

**A COMPARISON OF SCIENCE TEACHERS' AND
ENGINEERING STUDENTS' RANKINGS OF SCIENCE
AND TECHNOLOGY RELATED GLOBAL PROBLEMS**

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by

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DECLARATION

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ABSTRACT

Using 262 acknowledged science educators from 41 countries, Bybee developed a scale for measuring the ranked priorities of scientists, and others, with respect to twelve major global problems related to science and technology in 1984. In 1993 this scale was re-administered to samples of 76 Cape Town science educators, 55 Transkei science educators and 129 chemical engineering undergraduates at the University of Cape Town.

High correlations ranging from $r = 0.68$ to $r = 0.90$ were obtained among the four samples' mean ranked priorities on the scale as a whole, over the ten year period. Among the top six global problems in 1984, five still received consistently high overall prioritisation in 1993, namely: population growth; world hunger and food resources; human health and disease; air quality and atmosphere; and water resources. The mean ranking of war technology as a priority declined by seven places over the ten year period.

Educators surveyed in follow-up studies in 1993 made numerous recommendations for teaching these global problems. These included the use of the science-technology-society (STS) approach in science education; the introduction of a core school curriculum on environmental education; the encouragement of student participation in projects which help to reduce or eliminate such global problems; and the re-allocation of money spent on nuclear arms towards the satisfaction of human basic needs such as food, housing, health and water services.

In a follow-up survey of twenty lecturers in engineering at the University of Cape Town in 1993 and 1994 important goals and issues singled out by individuals included the provision of mass housing and infrastructure; sanitation; urbanisation; job creation; the abuse of high technology in communications; technological illiteracy among decision makers; abuse and reduction of oceanic

resources; photochemical smog; the prediction and possible control of droughts and floods; demands on the human race of the information explosion; electromagnetic wave hazards and pollution; resource depletion education and the dissemination of knowledge; the emergence and separation of C.P. Snow's "Two cultures"; and the myth of the peace dividend.

Several of these issues were then subsequently included in 1995 in an updated, modified and extended form of the Bybee Scale. Currently a reliable and validated 15-item Scale – emerging from the findings of this dissertation – is being employed by other research workers in various parts of the new South Africa. During 1995 its chief use has been offering relevant input into, and providing empirical justification for, fundamental aspects of the policy of the current Reconstruction and Development Programme, as set out in the 1995 White Paper of the Government of National Unity.

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LIST OF ABBREVIATIONS

AAAS	American Association for the Advancement of Science
AIDS	Acquired immune deficiency syndrome
ANC	African National Congress
BEd	Bachelor of Education
CEPD	Centre for Education Policy Development
CFCs	Chlorofluorocarbons
CMSA	A Curriculum Model for Education in South Africa
COBES	Computer-based Environmental Studies
COTEP	Committee on Teacher Education Policy
DBSA	Development Bank of Southern Africa
DEA	Department of Environment Affairs
DEAT	Department of Environmental Affairs and Tourism
FRD	Foundation for Research Development
GNU	Government of National Unity
GEC	General Education Certificate
IGU	International Geographical Union
IT	Information Technology
IUCN	International Union for the Conservation of Nature
NACA	National Association for Clean Air
NARST	National Association of Research in Science Teaching
NJIT	New Jersey Institute of Technology
NSTA	National Science Teachers' Association
PWW	Pretoria-Witwatersrand-Vereeniging
RDP	Reconstruction and Development Programme
SAFM	South African frequency modulation
STS	Science-Technology-Society
TEMPUS	Trans-European Mobility Scheme for University Studies
UK	United Kingdom
UMD	University of Minnesota, Duluth

UNEP	United Nations Environmental Programme
UNESCO	United Nations Educational, Scientific and Cultural Organisation
USICEE	UNESCO Supported International Centre for Engineering Education
WCED	World Commission on Environment and Development
WWF	World Wide Fund for Nature

LIST OF TABLES

	Page
Table 3.1: Countries represented by survey respondents in Sample 1 (after Bybee and Mau, 1986:601)	32
Table 4.1: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators (N=262) in 1984 (Sample 1)	39
Table 4.2: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators (N=76) in 1993 (Sample 2)	40
Table 4.3: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by University of Cape Town chemical engineering students (N=129) in 1993 (Sample 3)	41
Table 4.4: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Transkei science educators (N=55) in 1993 (Sample 4)	42
Table 4.5: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and Cape Town science educators in 1993	48
Table 4.6: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and Transkei science educators in 1993	49
Table 4.7: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and undergraduate chemical engineers in 1993	50
Table 4.8: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators in 1993 and Transkei science educators in 1993	51

Table 4.9:	The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators in 1993 and undergraduate chemical engineers in 1993 . . .	52
Table 4.10:	The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Transkei science educators in 1993 and undergraduate chemical engineers in 1993	53
Table 4.11:	Spearman's rank correlations	54
Table 5.1:	The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by four samples of science educators/engineers over a ten year period	59

APPENDIX A AND K:

Table 1.1:	Ranking of science and technology related global problems, after Bybee & Mau (1986:604)
Table 3.2:	Open-ended follow-up questionnaire given to lecturers in the Faculty of Engineering at the University of Cape Town
Table 5.2:	Ranking of science-and technology-related global problems in 1995: a proposed new instrument

LIST OF FIGURES

	Page
Figure 3.1: Map of the old South Africa highlighting the location of Transkei in the Eastern Cape region – Source: Juta’s New Large Print Atlas, 1985, Cape Town: Juta and Company Ltd	34
Figure 4.1: Mean priority scores for the four samples with respect to the twelve global problems, incorporated into the Bybee scale	44
Figure 5.1: Range of mean priority scores for the four samples for twelve global problems	64

TABLE OF CONTENTS

	Page
DECLARATION	i
ABSTRACT	ii
ACKNOWLEDGEMENTS	iv
LIST OF ABBREVIATIONS	v
CHAPTER 1: INTRODUCTION	1
1.1 ORIGIN AND BACKGROUND TO THE PROBLEM	1
1.2 FOCUS AND IMPORTANCE OF THE RESEARCH	5
1.3 PURPOSE OF THE RESEARCH	8
1.4 KEY QUESTIONS	9
1.5 NULL HYPOTHESES	10
1.6 CLARIFICATION OF TERMS	11
1.7 RESEARCH APPROACH AND DELIMITATION OF THE INVESTIGATION	12
1.8 ORGANISATION OF THE REMAINDER OF THE DISSERTATION	13
1.9 CHAPTER SUMMARY	13
CHAPTER 2: LITERATURE REVIEW	14
2.1 THEORETICAL FRAMEWORK OF THIS STUDY	14
2.1.1 The Theory of social control	14
2.1.2 Science-Technology-and-Society (STS) curriculum approach	15
2.1.3 Social engineering	15
2.1.4 The global environment and the Second Law of Thermodynamics	16
2.2 LITERATURE SURVEY	16
2.2.1 Increasing damage to the environment	17
2.2.2 Public response	18
2.2.3 Governmental and non-governmental responses	19
2.2.4 The emergence of universal environmental education ..	22
2.2.5 Emerging environmental education curricula	23

2.2.6 Environmental education curricula in engineering	24
2.2.7 National environmental education curricula	25
2.2.8 STS Curricula	26
2.2.9 A new science and technology policy for South Africa . .	27
2.3 FINDINGS AND CONCLUSIONS FROM THE LITERATURE SURVEY	29
CHAPTER 3: THE RESEARCH METHODOLOGY	31
3.1 THE SAMPLES	31
3.2 THE MEASURING INSTRUMENT	35
3.3 THE RESEARCH METHOD AND DATA COLLECTION PROCEDURES	35
3.3.1 Data collection in 1984	36
3.3.2 Data collection in 1993	36
CHAPTER 4: RESULTS	38
4.1 THE EMPIRICAL FINDINGS	38
4.2 NULL HYPOTHESES AND INTERCORRELATIONS	45
4.3 PRESENTATION OF THE QUALITATIVE FINDINGS	55
CHAPTER 5: DISCUSSION	58
5.1 DISCUSSION OF THE EMPIRICAL FINDINGS	58
5.2 DISCUSSION OF THE RESEARCH METHOD	65
5.3 CRITIQUE ON THE INSTRUMENT ITSELF	65
CHAPTER 6: CONCLUSIONS,IMPLICATIONS AND RECOMMENDATIONS	67
6.1 CONCLUSIONS	67
6.2 IMPLICATIONS	67
6.3 SUGGESTED RECOMMENDATIONS	68
6.4 CONSIDERATIONS WITH REGARD TO SCIENCE EDUCATION POLICY	70
6.5 RECOMMENDATIONS FOR FURTHER RESEARCH	71
LIST OF REFERENCES	73

APPENDICES:

Appendix A: College students' ranking of 12 science-related social problems in 1984; Ranking of science and technology related global problems, after Bybee & Mau (1986:604) and Open-ended follow-up questionnaire given to lecturers in the Faculty of Engineering at the University of Cape Town

Appendix B: Offprint of previously published work

Appendix C: South African Institute of Race Relations Survey (1994/1995)

Appendix D: Perceptions of professional ecologists and business leaders in South Africa on environmental issues

Appendix E: Global change and issues

Appendix F: Global calls for environmental education

Appendix G: 1995 chemical engineering curriculum at the University of Cape Town 1995

Appendix H: Critical values for Spearman's rank correlation coefficient

Appendix I: Photocopies of some of the recommendations made by Cape Town and Transkei science education

Appendix J: Documentation of the suggestions made in December 1993 by lecturers in the Faculty of Engineering at UCT

Appendix K: Table 5.2 and Xhosa version of Table 5.2

CHAPTER 1

INTRODUCTION

1.1 ORIGIN AND BACKGROUND TO THE PROBLEM

This investigation is an extension, update and corroboration of the work of Bybee and Mau (1986) and by Bybee and Najafi (1986) who, ten years ago, surveyed 262 internationally acknowledged science educators and 317 college science students. They found that, among the twelve global problems listed on their scale, the six which received high priority were: world hunger and food resources; population growth; air quality and the atmosphere; water resources; war technology; and human health and disease in the case of the international science educators as a group. In the case of the college science students in 1984, the problems of hazardous substances and energy shortages were also included in their list of priorities, since there were tied ranks in sixth position; with the human health and disease factor being ranked lower. A tabulated summary of this work is attached in Appendix A.

The present study, with samples of South African science and engineering educators and undergraduate engineering students in 1993 and 1994, uses Bybee's original instrument – reproduced in Appendix A in Table 1.1 – to update, monitor, compare and contrast the patterns of current priorities among these groups. It also seeks to account for any similarities and differences emerging in the trends during the last decade.

Part of the work for this dissertation has been published recently in the International Journal of Engineering Education 1994, vol. 10, no. 3, pp244-248, and this article is attached in Appendix B.

Faced with challenges which are both science-and-technology-related as part of the government's 1994/5 Reconstruction and Development Programme (ANC, 1994), South African educational planners now need a consensus of prioritised efforts. It is through school curricula, for example, that an **environmental ethic** might be instilled in the minds of the pupils by educators (Nightingale, 1994:59), and spread throughout society, if a study of the environment were to become a **core** subject in school curricula.

In a report by the Communications Manager of the Foundation for Research Development (FRD) (University of Cape Town, Monday Paper, 1995:3) it was stated that, to realise the goals of the Reconstruction and Development Programme (RDP), which include improving the quality of lives of all South Africans, the FRD intends to:

- promote an awareness of science, engineering and technology amongst the entire community;
- create a research environment which would train the next generation;
- ensure the growth of competitive industry by instilling a competitive mindset through research and technology development and the development of skills and expertise;
- increase participation in science, engineering and technology by the whole community; and
- sustain the environment.

The British Prime Minister, John Major, and the President of South Africa, Nelson Mandela, have signed a Memorandum on development cooperation (British Overseas Development, 1994:3). The Memorandum sets out the agreed areas of focus for 60 million pounds of bilateral aid over a period of three years. These funds are to be used in support of the RDP in priority areas stated as the following:

- education, with special emphasis on **English, Mathematics and Science** in schools;
- **health**, particularly reproductive and primary health care services;

- agriculture, developing **environmental policy**, rural development and sustainable **land use**; and
- support for small enterprises.

All the above priorities form part of the challenges facing the South African Government of National Unity (GNU).

Every year South Africa has been adding an extra million people to its population (Sunter, 1992:152). By the year 2030 another entire South African population should exist, assuming that the annual increment does not climb as the population increases. However, only 13.5 per cent of South Africa is categorised as arable land. Parts of that land are already severely overpopulated. For example, according to the Development Bank of Southern Africa (DBSA), the Pretoria-Witwatersrand-Vereeniging (PWW) area had the highest population density (365 people per square kilometre; followed by Kwazulu/Natal (94 people per square kilometre); and the area with the lowest population density (2.1 people per square kilometre) was the Northern Cape (South African Institute of Race Relations, Race Relations Survey, 1994/1994:20-21, see Appendix C).

Science educators, modern engineers and other groups of people have a multidimensional task in society. Their work involves meeting major human needs, including sustainable development (Hurry, 1994:22); environmental protection; designing and solving problems in real situations; anticipating health effects; and many others (Fenster, 1993; Bordogna, 1993; Jones, 1992).

Programmes which inculcate an awareness of social issues have been developed, for example, at the New Jersey Institute of Technology (Fenster, 1993) for chemical engineering students. This was a collaborative effort of three faculties namely: **Chemical Engineering**; **Humanities**; and **Science, Technology and Society**. Two goals of this programme were to foster independent thought and to develop a sense of cultural and intellectual breadth.

Such programmes also focus on the conservation of the environment and on the importance of applying scientific principles in identifying and solving science and technology related problems.

Stephan (1995:9) asserts that the engineering profession is a major contributor to our technology-based society which has created many global problems. Thus, the engineering professionals should develop professional ethics leading to environmental – and human – friendly technologies.

The widespread concern about the relationship between humankind and the environment has led to the use of information technology (IT) to improve and introduce new exciting approaches to teaching and learning. Squires, Bosler and Tsankova (1994:507) claim, "given the needs to develop new environmental education curricula and related teaching practice there is a strong case for investigating the potential of IT to support, enhance and develop work in environmental education".

Computer-based Environmental Studies (COBES), – which is a current Trans-European Mobility Scheme for University Studies (TEMPUS) project based on the cooperation between the Institute for Science Education (Germany), King's College London (UK) and the Technical University-Sofia (Bulgaria) – is designed to explore these issues through the formal development of university-level environmental studies curricula which make extensive use of IT, and the informal promotion of public awareness of environmental issues through the establishment of a national river pollution data exchange network (Squires, et al., 1994:507).

It is in this context that, over a ten year period, the Bybee scale may be a useful, preliminary, convenient and appropriate instrument for measuring changing ranked priorities among science educators, engineers and other groups of scientists with respect to twelve of the most important established global problems related to science and technology (Bybee and Mau, 1986:604)

while, at the same time, possibly developing and extending the scale for further use in the 1990s. Should other pertinent and clearly focused issues begin to emerge in future surveys, modifications to the original global scale may be recommended – perhaps even being adapted for local or African contexts, where appropriate.

1.2 FOCUS AND IMPORTANCE OF THE RESEARCH

Seaman (1993:41) has claimed that, since South Africa is a beautiful country in its conservation, nature and environment, if it were analogous to an appliance, then one would need a specification of instructions in order to understand and preserve it. He went on to say that South Africa was facing well defined major problems (although these had not been prioritised) such as:

- an increase in climatic variability
- desertification
- population increase
- acid rain in critical crop-growing areas
- political uncertainty [at that time of his writing in 1993]
- manipulation of water resources
- ignorance, illiteracy and lack of electricity
- national poverty and low economic growth
- AIDS
- war

Thus Bybee's instrument appears to be particularly useful and relevant, since so many of these aspects mentioned by Seaman in 1993 have been included already in Bybee's scale.

Seaman (1993:41) also emphasised the fact that there was a need to preserve our life support systems in South Africa, and that everybody was to be

convinced of the need. A major channel through which this might occur is education.

Hence, this research focuses on the importance of teaching the major global social problems facing humankind which are science-and-technology-related. The science curriculum approach offered in our schools should relate the content and application of science to the learners' environment and needs (SCISA, 1989; Ndodana, 1993:9; Doidge, 1995:111) and this might be achieved through integrated science and a thematic approach to education (Pare, 1995:137-140; CEPD, 1995:5). Such a synthesis could incorporate subjects like physics; chemistry; biology; elements of earth and space; mathematics; economics; and other subjects, including environmental issues (Bouthyette, 1991; Ward, 1991; Paldy, 1992; Siebert, 1992; Pare, 1995).

A global change activity project was initiated at the Ohio State University (Mayer, 1990). The main aim of this project was to develop secondary science curriculum modules for global change in education to be fused into the high school science curriculum. The global change topics included the greenhouse effect and global warming; ozone; deforestation and its effects on bio-diversity; El Nino; desertification; remote sensing; climate modelling; earthquake prediction; volcanic eruptions; acid rain; and the impact of technology on the study of the earth. The project included input from science teachers, university educators and scientists of varied discipline.

The Zanzibar Science Camp Project (Lange, 1995:125-132) which was initiated in 1988 still continues to function. The main aim of this project is to create an opportunity for people from all sectors of the education staff and students in Zanzibar to work together in solving potential conflicts on issues involving environmental and science education.

The United Nations Educational, Scientific and Cultural Organisation (UNESCO) Supported International Centre for Engineering Education (USICEE)

combines the aspects of education and engineering. According to Stephan (1995:13) USICEE has the ideal capabilities to implement a new approach in engineering education. Thus it should think about the implementation of new engineering principles, considering sustainable technology in its objectives.

The Centre for Education Policy Development (CEPD, 1995:28) has presented a framework for a new core science curriculum for the new South Africa in accordance with the aims proposed by the **ANC Discussion Document on Education Policy** (ANC, 1994). Input from teachers, curriculum developers, policy makers and other stakeholders in the field of science education was expected subsequent to the presentation of this document.

The philosophy embedded in the new curriculum was that:

- it should reflect the application of basic science ideas to societal issues;
- science and technology curriculum should see the learner's needs and interests as a base on which knowledge may be constructed;
- the curriculum should prepare the learners to be independent and responsible;
- science should reflect the participatory and collaborative way in which knowledge is generated; and
- pupils should feel empowered to exert their influence on an environment where technology has a rapidly expanding role (CEPD, 1995:8).

Against this background, the present local investigation is important for the following reasons:

1. There is a need to include **environmental issues** in modern South African school science curricula (IGU Commission on Geographical Education, 1994:11; Government White Paper on Education and Training, 1995:22).

2. The teaching of global problems facing human beings could bring about an increase in **environmental awareness** and a culture of **environmental protection and preservation** (ANC, 1994:40).
3. Consistently high prioritisation of a similar set of problems over a period of ten years may indicate that only a slight or even no change has occurred in the resolution of important global problems facing humankind during the past decade, despite the best efforts of concerned scientists and science educators. This would have implications for the sustaining of a core curriculum in the sciences.

1.3 PURPOSE OF THE RESEARCH

The first aim of this research is to determine and explain which global Science-Technology-Society (STS) problems remained highly prioritised in 1993 subsequent to earlier high prioritisations made in 1984. The study seeks to establish this by determining the significance and importance of positive rank order correlations occurring among samples of international science educators, Cape Town science educators, Transkei science educators and University of Cape Town engineering undergraduates.

Secondly, this investigation seeks to gather recommendations proposed by South African science and engineering educators for instructional methods and the teaching of these global problems.

The third aim is to produce, for further research, a modified, adapted, extended and validated form of the original Bybee instrument. It is proposed for use in 1994 and 1995 as part of the corroboration of, and justification for, basic principles selected in the policies and framework of the new South Africa's Reconstruction and Development Programme, with special reference to science and technology education.

1.4 KEY QUESTIONS

The present study thus seeks to answer the following specific questions:

1. How do Cape Town science educators (N=76) in 1993 prioritise twelve global problems related to science and technology, compared to international science educators (N=262) who ranked them in 1984?
2. How do Transkei science educators (N=55) in 1993 prioritise twelve global problems related to science and technology, compared to international science educators (N=262) who ranked them in 1984?
3. How do chemical engineering undergraduates (N=129) at the University of Cape Town in 1993 prioritise twelve global problems related to science and technology, compared to international science educators (N=129) who ranked them in 1984?
4. Do science educators in Cape Town (N=76) in 1993 rank science-and-technology-related global problems in the same order of importance as their counterpart science educators in the Transkei (N=55) in 1993?
5. Do chemical engineering undergraduates of the University of Cape Town (N=129) in 1993 rank science-and-technology-related global problems in the same order of importance as Cape Town science educators (N=55) in 1993 and Transkei science educators (N=55) in 1993?
6. What suggestions and recommendations do science educators propose with regard to the content and method of the classroom teaching of these global Science-Technology-Society problems?

Answer to these questions may also result in recommendations for modifying or extending the original 12-item scale to a 15-item scale, or for reducing it to

a more concise relevant 10-item scale, or for recommending the use of different versions of the new scale in geographical areas with different cultural perceptions of global problems, depending on the world view of the respondents; and so on.

1.5 NULL HYPOTHESES

Six null hypotheses were tested in this investigation:

Null Hypothesis 1

There will be no statistically significant correlation between the **international science educators** in 1984 (N=262) and **Cape Town science educators** in 1993 (N=76) with regard to their mean ranking of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Null Hypothesis 2

There will be no statistically significant correlation between the **international science educators** (N=262) and **Transkei science educators** (N=55) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Null Hypothesis 3

There will be no statistically significant correlation between the **international science educators** (N=262) and the **chemical engineering undergraduate students** of the University of Cape Town (N=129) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Null Hypothesis 4

There will be no statistically significant correlation between the **Cape Town science educators** (N=76) and the **Transkei science educators** (N=55) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Null Hypothesis 5

There will be no statistically significant correlation between the **Cape Town science educators** (N=76) and the **chemical engineering undergraduates** of the University of Cape Town (N=129) with regard to their mean rankings of the twelve listed global problems of prime important related to science and technology on the Bybee scale.

Null Hypothesis 6

There will be no statistically significant correlation between **Transkei science educators** (N=55) and **chemical engineering undergraduates** of the University of Cape Town (N=129) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

1.6 CLARIFICATION OF TERMS

Science-Technology-Society is the term applied to the effort to provide a real world context for the study of science, and for the pursuit of science itself. It focuses upon current issues and attempts at their resolution as the best way to prepare people for current future citizenship role (Ost and Yager, 1993:282).

Global problems related to science and technology, as determined in 1984 by acknowledged science educators from 41 countries, are defined in the instrument used for data collection (Bybee and Mau, 1986:604) presented in Table 1.1 in Appendix A. These problems are considered global in nature

because they are widely encountered in both the First and the Third World Countries (World Commission on Environment and Development, 1987:2-11).

The term **samples** which has been used throughout the dissertation refers specifically to the **group** of subjects.

'**Science educators**' is interchangeably used with **science teachers** in the case of **Sample 2** which is comprised of Cape Town group of subjects.

1.7 RESEARCH APPROACH AND DELIMITATION OF THE INVESTIGATION

This pioneering South African study has been restricted to four samples of surveyed respondents which differ in terms of their geographical setting; educational background; age as well as time lag between this investigation and Bybee and Mau's study. For the purposes of this study the group of 262 international science educators is designated as **Sample 1**. **Sample 2** comprises 76 Cape Town science educators surveyed as an intact group in August 1993. **Sample 3** consists of 129 chemical engineering undergraduates at the University of Cape Town canvassed as whole classes in October 1993 in years 2, 3 and 4, combined into a whole. **Sample 4** comprises 55 Transkei science educators surveyed in October 1993.

A subsidiary fifth group consists of 20 lecturers in engineering at the University of Cape Town also responded in December 1993 to an open-ended follow-up questionnaire. This appears in Table 3.2 in Appendix A.

1.8 ORGANISATION OF THE REMAINDER OF THE DISSERTATION

The next five chapters are arranged as follows:

Chapter 2 elaborates on the theoretical background to the problem; Chapter 3 describes the detailed research methodology; and Chapter 4 presents the findings derived from the data. A discussion of the empirical results, and a critique of the research method and of the instrument itself, are presented in Chapter 5; and the last chapter sets out the conclusions, implications and recommendations for further research.

1.9 CHAPTER SUMMARY

This research is an extension of, and investigation into, the long-term consistency of findings reported by Bybee and Mau (1986) with international science educators, and by Bybee and Najafi (1986) with college students. The background, focus, importance and purpose of this investigation have been discussed, and the research approach introduced. The next chapter presents the theoretical framework of this study in more detail.

CHAPTER 2

LITERATURE REVIEW

This chapter is divided into two sections:

- 2.1 Theoretical framework of this study.
- 2.2 Literature survey.
- 2.2 Findings and conclusions from the literature survey.

2.1 THEORETICAL FRAMEWORK OF THIS STUDY

This investigation is based on a number of theories and approaches such as:

- (a) The Theory of Social Control;
- (b) The S-T-S Curricula approach;
- (c) Social Engineering approach;
- (d) The Global Environment and the Second Law of Thermodynamics.

The above mentioned theories are projected in the literature survey and special reference has been made to:

- 2.1.1 The Theory of Social Control
- 2.1.2 STS Curricula
- 2.1.3 Social Engineering
- 2.1.4 Second Law of Thermodynamics

2.1.1 The theory of social control

The behaviour of any human being, whatever his society, is invariably influenced by a number of forces such as: the personality factors; the situational factors and the social control factors (LaPiere, 1954:64-65). LaPiere further asserts that social control is the mediator between the personality of an

individual and the specific situation in which he/she acts. This type of control is usually exercised by an intimate group which induces conformity of the individual to the norms and standards of that particular group or society. The individual tends to desire for a particular kind of status that the group provides. The individual's regard for social status makes him subject to **social control**.

In view of the above theory the individual's behaviour must be modified to defend one's natural world or environment. He must search for a dynamic and creative balance in which interaction between himself and nature will favour the life giving exaltation of both.

2.1.2 Science-Technology-and-Society (STS) curriculum approach

From time immemorial science, technology and societal needs have been taught in isolation in schools. The major premise for the STS approach is to improve education in science and technology to provide a sound base for decisions towards a better future and the satisfaction of human needs. Consideration of human needs presumes that we must actively seek ways to improve the quality of people's lives. This implies dealing with values in our education, especially in science and technology education (Baez, 1985).

Science should constitute the foundation in which proper ecological value-judgements are based, and technology should provide the practical means of solving the ecological problems posed by industrial and other societies.

2.1.3 Social engineering

Scientific and technological knowledge related to environmental programmes is currently integrated into formal engineering programmes, to improve the training of engineers. This is to prepare them not only to meet the development changes of society, but also to be sensitive to the environmental

damages that can result from the very process of development (De Camargo, 1985).

The preservation of natural resources together with accelerated economic development of a country – to guarantee an acceptable quality of life to the population – can only be accomplished through a wise application of scientific and technological knowledge, not only to solve existing problems but to prevent future ones (De Camargo, 1985).

2.1.4 *The global environment and the Second Law of Thermodynamics*

The planet used to be a large world in which human activities and their effects were neatly compartmentalised. These compartments began to dissolve resulting into various global 'crises', namely, the environmental crisis; a development crisis and an energy crisis (World Commission on Environment and Development, 1987:4). The Second Law of Thermodynamics states that systems in equilibrium cannot change without the action of some external agent, and in all real, non-reversible process energy is degraded to a less useful form (Kennedy, 1982:41).

Man has dominated his natural environment in an attempt to create healthy surroundings in which human skills, intellect and spirit can be developed to their highest potential. This has resulted into propelled growth and consumption of goods and energy which threatens to destroy the equilibrium of nature, and to jeopardise the destiny of human kind (Bauer, 1985).

2.2 LITERATURE SURVEY

A large body of work exists dealing with the global problems facing humans and other living creatures world-wide. No specific studies have been found establishing consensus on the prioritisation of these global problems, other than

the work done by Bybee and Mau (1986), Bybee and Najafi (1986), and the perceptions of professional ecologists and business leaders in South Africa (Preston, Fuggle and Siegfried, 1989) on environmental issues in South Africa, which are included in Appendix D.

2.2.1 *Increasing damage to the environment*

Today's environmental challenges such as poverty, soil erosion, desertification, global warming, air pollution, water pollution, depletion of the ozone layer, acid rain and many others, arise as a result of improving our living conditions (World Commission on Environment and Development (WCED), 1987). The growing demands, that cause over-exploitation of scarce resources generated by our living standards, reproduce these challenges.

This is supported by Meadows et al. (1992:100) who gave a synopsis on the causes of environmental degradation using a formula represented by the acronym IPAT:

$$\text{"Impact} = \text{Population} \times \text{Affluence} \times \text{Technology"}$$

The above formula means that the impact caused by any population upon the planet's sources and sinks is the product of its population (P) times its level of affluence (A) multiplied by the damage done by particular technology (T) that supports the affluence. The above mentioned challenges are included in the Bybee scale reproduced in Appendix A.

Baez (1991:133) contends that our environment is suffocating and crumbling under the impact of human action leading to global collapse. The fact that science and technology have formed a major part of our culture and provided us with many benefits cannot be disputed, but they have "had serious social and sociological impacts and repercussions" as well (Husen, 1991:5).

Concerned individuals and groups of people such as members of the Club of Rome (1972, cited in Meadows et al., 1992) have shown that if growth trends

continued unchanged, the limits to physical growth on the planet would be reached within a hundred years. This created headlines around the world and caused tensions among industrialists. Many refused to accept its conclusions, yet the global scientific evidence since then confirmed it (Porritt, 1990; Clarke, 1991; Sunter, 1992 and Meadows et al., 1992).

Technology has encouraged over-consumption of renewable and non-renewable natural resources (Wright and Govindarajan, 1992:269) and increased regional and global environmental threats, such as acid rain, global warming, depletion of the ozone layer, pollution of seas, problems of waste treatments and increased use of chemicals (Wijkman, 1991:181-186).

Other existing problems include: destruction of rain forests, land degradation and overpopulation which is growing at an alarming rate throughout the world. However, there is reason to believe that South Africa's population is not disastrously high. Given a high agricultural policy, it can easily feed itself from its resources (Clarke, 1991:225; ANC, 1994a:14).

Some of the above mentioned problems are included in the UNESCO-UNEP (1993) document, labelled as **global change and issues** (Department of Environmental Affairs and Tourism, 1995:17) which is included in Appendix E and most of them appear again, in the Bybee scale presented in Appendix A.

2.2.2 Public response

Public awareness and concern about these issues is also acknowledged. This is confirmed by its reaction to these environmental issues. A few examples are presented:

– Furore over toxic waste

Environmentalists are threatening to take legal action against the government over a cabinet committee decision to veto an independent commission of enquiry into the importation of hazardous waste. National coordinator of the

forum (Environmental Justice Networking Forum) said the government was engaging in a cover-up, and the public has a right to know what toxic material was being imported and exported (Sunday Times, September 10, 1995:5).

– **Now its war on water wastage**

In spite of it seeming to have rained enough this winter to make everything sodden in the Western Cape there is a water crisis (Weekend Argus, September 16/17, 1995:14).

– **Oil deal with Iran is a victim of sabotage**

The dispute over an oil deal with Iran is perceived as sabotaging South Africa's economy and the Reconstruction and Development Programme (RDP) rather than fears nursed by an environmental group. The argument about environmental damage due to oil related activities in Saldanha Bay is claimed to be a flimsy excuse to cover-up a broader agenda of economic sabotage as this deal would be a boost for the RDP and the poor people of South Africa (Sunday Times, September 10, 1995:21).

– **Fuel dumped in Little Lotus River highlights threat to vlei**

A spokesperson for the Zeekoei Vlei Environmental Forum said that Zeekoei Vlei had been so badly affected by pollutants and excessive weed growth that its function as a recreational asset is threatened. He also claimed it was hard to believe that people could be so thoughtless about the environment (Argus, September 14, 1995:15).

– **Nuclear threat to volcano**

A French volcanologist had warned that more nuclear tests at Mururoa atoll in the South Pacific could cause the collapse of a flank of the extinct underwater volcano, leading to a big release of radioactivity (The Times Higher, July 21, 1995:10).

The above mentioned examples form part of the great human challenges to be combatted for building a sustainable future.

2.2.3 Governmental and non-governmental responses

A wide range of responses have been shown by various environmental authorities, governmental and non-governmental organisations supporting

environmental movements locally, nationally and internationally by embarking on active public participation. Examples of such organisations are:

- The International Union for the Conservation of Nature and Natural Resources (IUCN);
- World Wide Fund for Nature (WWF);
- United Nations Environmental Programme (UNEP);
- Air and Waste Management Association of the United States of America and Canada which led to the formation of the National Association for Clean Air (NACA) in South Africa.
- The Solid Waste Management of the City of Johannesburg in South Africa (with a mission to improve the quality of the environment by effectively managing the waste stream);
- Natal Parks Board;
- The Wildlife Society of Southern Africa; and
- Environmental Education Association of South Africa.

Public participation requires citizens who understand the dynamics which operate within their environments, and who have attitudes and skills necessary to contribute positively and actively to the maintenance, planning and improvement of their environments. This is supported by the 1995 South African Reconstruction and Development Programme in which emphasis has been made on the Government of National Unity to work towards:

a participatory decision making process around environmental issues, empowering communities to manage their natural environments . . . increasing the capacity of citizens to monitor and prevent the dumping of toxic wastes . . . to empower communities to act on environmental issues and to promote an environmental ethic . . . to promote an active participation of civil society (ANC, 1994a:39-40).

Environmental degradation has so long been associated with the poor and the illiterate because of their close proximity to many of the 'most serious' environmental problems. Over-grazing, harmful land use practices leading to soil erosion, denuded forests, surface water pollution, and mismanagement of natural resources are all laid at the feet of the poor (Porritt, 1990:164;

Department of Environmental Affairs and Tourism (DEAT), 1995:20-22). However, Orr (1990:46) asserts that people who are largely responsible for the global crises are the educated "the BAs, LLBs, MBAs and PhDs" and he queried the kind of education they have. The global crisis is, therefore, everybody's responsibility.

The concept of the environment does not only refer to the biophysical world but also incorporates the economic, the social and the political world (DEAT, 1995:11-13). This is supported by the RDP (ANC, 1994a:75) when referring to the position of the South African economy which is claimed to be in "deep-seated" structural crisis and in need of **fundamental reconstruction**. This crisis is consequential to the apartheid policies of the previous South African governments (before the 27 of April 1994) which Khan (1992:96) refers to as "the environmentally destructive role played by apartheid laws".

According to Khan (1992:98) environmental challenges such as poverty – which is a direct result of unemployment, disproportionate income and wealth – leads to violence and instability which have permeated our country.

The general environmental policy (Department of Environment Affairs, 1994:7) – which is in accordance with section 2 of the Environment Conservation Act, 1989 (Act 73 of 1989) – states that economic development is supported provided there is no overstraining of the environment and natural resources.

Economic development and environmental sustainability become a complex issue when the effects of the economic development are adverse. Two specific cases are:

- (i) **Toxic waste 'imperialism'** (Cape Times, Business Report, September 7, 1995:22).
- (iii) **Global warming** (The Times Higher, July 21, 1995:21).

In the first case businessmen could no longer sustain the ban on toxic imperialism that was signed under the auspices of the Basle Convention in 1994 until the end of 1997; this had to be reviewed by September 1995 (Cape Times, Business Report, September 7, 1995:22). National policy makers had to adopt a 'wait and see' attitude as the second case imposed reductions or elimination on the use of fossil fuels (The Times Higher, July 21, 1995:21). Both cases are irreconcilable with environmental sustainability.

2.2.4 *The emergence of universal environmental education*

If all citizens can organise themselves socially, and draw attention to situations of environmental concern (Gomez-Granell and Cervera-March, 1993:554), it could be possible for them to participate responsibly in maintaining and managing a habitable environment for now and future generations. According to the President's Council on National Environmental Management System (DEA, 1993:4) the environmental management requires a partnership between the government and its people. It also stressed that no management system, however sophisticated, will be able to deal with environmental degradation unless an **environmental ethic** develops among the people.

An environmental ethic can be developed, provided that education is considered a priority response to environmental crises – especially environmental education which Blignaut (1993:1) defines as "a dynamic process of lifelong education which is evolving both globally and locally".

She further stresses that an environmental ethic is concerned fundamentally with the way humans behave towards the environment and it also aims at developing people who are capable of addressing environmental problems.

In a report on the conference on The Implementation of the RDP as far as the environment is concerned (Council for the Environment, 1994:16) environmental education is defined as "education for sustainable living which

seeks to create responsible behaviour patterns and attitudes towards the environment and which empowers individuals, groups and communities for environmental commitment".

The above mentioned report raised concerns about the omission of the environment or environmental issues in the RDP White Paper (Council for the Environment, 1994:4) and claimed that environment underpins the RDP. It was also emphasised that formal schooling should go hand in hand with environmental education because the implementation of the RDP might cause pressure on the natural resources and the environment, for example, land for housing; demand for clean water; better health services and population growth.

Thus, it is imperative that literacy skills be acquired by the people to empower them to uplift themselves to a better quality of life and for the benefit of the environment, and these could be attained through formal education.

A summary presented by Blignaut (1991) on the Global calls for Environmental education and its developments in South Africa until 1989 is included in Appendix F.

This summary reveals that attempts have been made to incorporate environmental education in formal education but environmental education projects have failed (O'Donoghue and McNaught, 1991:393) as a result of the so-called 'centre-to-periphery' models of curriculum development – where teachers become curriculum implementors rather than participants in curriculum development – as well as poor communication.

2.2.5 Emerging environmental education curricula

Some of the fundamental problems for the implementation of environmental education are:

- the absence of a curriculum which integrates scientific, social, theoretical and practical content (Gomez-Granell and Cervera-March, 1993:564);
- limited resources;
- teachers with little knowledge about environmental education; and
- very little support for teacher development on environmental education (Committee on Teacher Education Policy, 1995).

However, in view of an ongoing debate on the fusion of environmental education into formal education, a working document – which is a contribution to this debate – has gained so much momentum that a curriculum framework for courses at the primary, secondary and tertiary levels has been proposed:

- an integrated curriculum approach in the Primary Phase;
- an integrated subject or modular approach in the Secondary Phase;
and
- a discrete subject in the Tertiary Phase (Council for the Environment, 1993:7).

Even though environmental problems have existed for a while (Sloep et al., 1992), the academic world saw itself confronted with a **new challenge** for which it had not prepared itself namely, the teaching of students so that they become specialists in dealing with environmental problems.

2.2.6 Environmental education curricula in engineering

Teaching about global problems in the engineering field appears to be receiving particular attention. This is supported, for example, by a relatively new educational programme developed for civil engineers at the University of Minnesota, Duluth (UMD) known as **environmental engineering** which has replaced sanitary engineering (Dorland and Baria, 1995:178). This course deals with solutions of problems of environmental sanitation, notably the

provision of safe, palatable, and copious public water supplies; adequate drainage of urban and rural areas for proper sanitation; control of the atmosphere, water and soil pollution; and the social and the environmental impacts of these solutions.

A programme for chemical engineering students was also designed such that it included a sequence of two courses that dealt with processing of hazardous waste (Dorland and Baria, 1995:179). Thus, in future, this programme would enable them to meet important needs for maintaining and improving the environment. New other engineering programmes have been developed in the various parts of the world, for example, at the University of Cape Town with chemical engineering students (see Appendix G).

2.2.7 National environmental education curricula

Human society undergoes continuous reconstruction, and to address this reconstruction there needs to be an education policy which might encourage courses of action to address societal problems. The above statement is implicitly supported by the directive principles of the national education policy (National Education Policy Bill, 1995:6), which states that it is directed towards the cultivation of "skills, disciplines and capacities necessary for reconstruction and development".

Attempts by the former South African government and its education system to bring about a policy for environmental education in formal education has not fully succeeded. Reference can be made for example, to the Curriculum Model for Education in South Africa (DNE, 1991) and to the White Paper on Environmental Education (1989). The legitimacy of the White Paper was questioned because there was no wide representation of the communities. Presently there is a discussion document which aims at:

- providing guidelines for a process of establishing an environmental education policy for formal education in South Africa; and
- providing a framework for environmental education curriculum development in formal education (DEAT, 1995).

Environmental issues and problems can be dealt with in different ways within the school curriculum, for example:

- in cross curricular themes;
- integrated into different subjects; and
- as modules and projects (Bradley, 1995; Lange, 1995; Pare, 1995 and Centre for Education Policy Department, 1995).

2.2.8 STS Curricula

One of the current relevant approaches advocated for the implementation of societal issues in science education is the Science-Technology-Society (STS) approach. This approach has been established already in many countries around the world as a major force in science education development for over fifteen or more years (Pedretti and Hodson, 1995:463).

Its proponents claim that the students' career awareness in science and technology or/and environmental awareness becomes improved since information and skills acquired are related to the world of work and to the students' daily activities (Doidge, 1995:112). Critics of the current science curriculum such as the ANC's discussion document on education policy (1994) asserts that the science curriculum is academic, abstract, outmoded, overloaded and de-contextualised. However, grounding content in socially and personally relevant contexts – which the STS approach provides – motivates the students to construct understanding that is personally relevant, meaningful and important.

Hodson (1994, cited in Pedretti and Hodson 1995:465) argues that we should regard an issues-based approach – advocated by the STS model – as having four levels:

- Level 1 Students can be made aware of the societal and environmental impact of science and technology and alerted to the existence of alternative practices.
- Level 2 They can be sensitised to the socio-political nature of scientific and technological practice.
- Level 3 They may be committed to the fight to establish more socially just and environmentally sustainable practices.
- Level 4 Students can acquire the knowledge and skills to intervene effectively in the decision-making processes and ensure that alternative voices, and their underlying interests and values, are brought to bear on policy decisions.

If all the above mentioned levels could be attained by the students, they would be regarded as scientific, technological and environmentally literate.

2.2.9 A new science and technology policy for South Africa

Branscomb (1994:5) claims that one of the imperatives which could effect change in the South African science and technology policy is "a rapid restructuring of mathematics, science, research and technical institutions to create opportunities for Africans and other disadvantaged citizens to participate to the full extent of their natural abilities and to create a new cadre of technical leaders".

Responding to the above call the Centre for Education Policy Development (CEPD) has proposed a new science and technology curriculum for the General Education Certificate (GEC) with their aims based on the ANC proposal which

overlap with the aims of the STS. To quote but a few, the following aims are presented. The science curriculum will:-

- 2.2 provide students with an understanding of the complex interdependent and evolving relationship between science, technology, society and the natural and manufactured environment;
- 2.3 develop scientific and technological skills and abilities needed in the economic, social, civil, ethical and cultural contexts of everyday life in South Africa;
- 2.5 develop the positive values and sense of responsibility needed for participation in the creation, development and maintenance of a democratic and just society, a prosperous economy and a healthy environment which will serve the needs of all citizens; and
- 2.10 create an awareness of the importance of conserving the environment (CEPD, 1995:9).

The primary motivation to make STS an important part of the science curriculum is the realisation that the effect of science and technology on society must be understood by each member of society (Mayer, 1995:388). Not only will citizens and leaders have to be more scientific and technologically literate, but they will also be more aware of the limitations of science and technology in solving environmental problems in our society.

The Policy Framework for Education and Training stresses that the curriculum for teacher education will strive at developing an environmental awareness among student teachers (African National Congress, 1995:55), understanding, skills, and a commitment to action through the subjects they teach. This could be addressed through **teacher education**, by making it more practically oriented towards wider issues and problems in their immediate communities (socio-economic issues). Teachers may be educated to be proactive than reactive (Committee on Teacher Education Policy, 1995:41).

A greater challenge may exist to educate in-service teachers because suitably trained personnel might play a major role at spreading the impact of science

and technology in society (Department of Environmental Affairs and Tourism, 1995).

The Foundation for Research and Development – which is a funding agency with a mission to develop the South African human-resource potential in science, engineering and technology – plays a significant role in providing for the social and economic needs of this country.

Tergart (1994:27) contends that funds are to be set aside to direct research into those areas which are relevant to wealth creation, improvement of the quality of life and the preservation of the environment. He goes on to say that it is imperative that **cooperative research centres** are formed to link government agencies, academia and industry on projects of regional and national significance.

This concept, he claims, has been adopted in Australia and has already changed the research culture of that country (Tergart, 1994:18).

In a discussion document on Science Research Policy in South Africa (Ellis, 1994:197-199), it has been explicitly stated that South Africa has a sound basis for environmental studies and management, and research policy needs to be developed to carry out and support required investigations.

2.3 FINDINGS AND CONCLUSIONS FROM THE LITERATURE SURVEY

Important issues which have surfaced from the literature survey, and which motivate a further study with the Bybee scale in 1994, are as follows:

- (i) There is a need to investigate the possibility and desirability of developing an integrated science curriculum, the use of an STS approach, and the infusion of environmental education in the formal education system.

- (ii) There is a new challenge to teach pupils about unresolved global problems and instil in them a sense of global responsibility.
- (iii) New programmes have emerged from the engineering field in an attempt to combat side effects caused by science and technology on the environment.
- (iv) An educational policy which encourages environmental sustainability is to be developed and implemented on the basis of empirically derived research findings in the classroom.
- (v) There appears to be a need for the school system to prepare students who are scientifically, technologically and environmentally literate.
- (vi) Teacher education also has a role of preparing teachers who are more environmentally aware and informed.
- (vii) There is a need to develop research centres which would serve as a link between the government, industry and academia.
- (viii) Future political, business and science leaders need to develop policies which would secure a sustainable environment.

Finally, the legislation of a sound environmental policy could foster a rethink of environmental priorities among politicians, industrialists and members of society.

The next chapter presents the research methodology for this study.

CHAPTER 3

THE RESEARCH METHODOLOGY

The three methodological aspects described in this chapter are:

- 3.1 The samples.
- 3.2 The measuring instrument.
- 3.3 The research method, and data collection procedures.

3.1 THE SAMPLES

Four samples of respondents were used in this study.

Sample 1 comprised 262 acknowledged international science educators from 41 countries who helped in refining the instrument originally developed by Bybee in 1984. These science educators were members of professional organisations such as the National Association of Research in Science Teaching (NARST), the American Association for the Advancement of Science (AAAS), and the National Science Teachers' Association (NSTA). Most of the respondents were male [75,2%] over 41 years of age [75.0%] and held the PhD or EdD degree [70.9%]. The majority worked in a college or university [58.7%]. The highest type of employment was research or curriculum development [18.2%].

Most of the respondents categorised their work as tertiary science educators [78.5%] followed by secondary level science teachers [8.3%] and social scientists [4.3%] (Bybee and Mau, 1986:601). The countries from which the science educators responded and the number (represented as a percentage of the total response) from the different countries are presented in Table 3.1.

Table 3.1: Countries represented by survey respondents in Sample 1 (after Bybee and Mau, 1986:601)

Australia	6.6%	Panama	.7%
Belgium	.3%	Philippines	1.1%
Botswana	.7%	Portugal	.3%
Brazil	1.9%	Samoa	.3%
Canada	18.8%	Sierra Leone	.3%
China (PRC)	.7%	Singapore	.3%
Costa Rica	.3%	South Africa	1.5%
Egypt	1.1%	Spain	1.5%
France	.7%	Sweden	.3%
Ghana	.3%	Switzerland	1.1%
India	.3%	Taiwan (ROC)	.7%
Indonesia	.7%	Tanzania	.3%
Israel	6.0%	United Kingdom	7.7%
Italy	2.7%	United States	29.9%
Japan	1.5%	Venezuela	.3%
Jordan	.7%	West Germany	1.9%
Korea	1.1%	West Indies	1.5%
Lebanon	.7%	Yugoslavia	.3%
Malaysia	.7%	Zambia	.3%
Netherlands	2.7%	Zimbabwe	.3%
Nigeria	1.9%		

Sample 2 comprised an opportunistic sample of 76 Cape Town science educators surveyed as an intact group in August 1993. As this was a convenient sample available at short notice, the researcher did not gather precisely how many of the respondents were male or female, although the genders appeared to be evenly represented. The researcher assumes that, since these respondents were attending a subject-specific workshop in biology when they were responding to the questionnaires, almost all were biology teachers from local secondary schools.

Sample 3 consisted of 129 full-time chemical engineering undergraduates at the University of Cape Town in 1993. The respondents were from classes of students in years 2, 3 and 4, combined into a whole. Their age range was mostly between 18 and 23 years. The ratio of females to males was 1:25 and they were of various groups with an approximately even distribution of 10:13 blacks to whites.

Sample 4 comprised 55 Transkei science educators at secondary and tertiary levels. Respondents were offering either biology, physical science and mathematics; or biology, general science and mathematics; or biology alone; or physical science and mathematics; or geography alone. The approximate ratio of males to females was 2:3. The majority were college lecturers (80%) and the remaining 20% were secondary school teachers. Their age range was between 25 and 45 years, and they were of the same cultural group. Their home language was Xhosa.

Transkei is the former so-called 'independent' state which has been reincorporated into South Africa and located in the Eastern Cape region as depicted in Figure 3.1.



Figure 3.1: Map of the old South Africa highlighting the location of Transkei in the Eastern Cape region – Source: Juta's New Large Print Atlas, 1985, Cape Town: Juta and Company Ltd

A fifth group of volunteers, who responded anonymously to an open-ended follow-up questionnaire in 1993, comprised a group of twenty male lecturers in engineering at the University of Cape Town. The survey questionnaire appears in Table 3.2 in Appendix A.

3.2 THE MEASURING INSTRUMENT

Initially a twelve-item instrument developed by Bybee for use with scientists (Bybee, 1984a), and with college students (Bybee and Najafi, 1986) was used for data collection. This instrument was originally developed for the group designated Sample 1 in 1984.

In 1993 a Cape Town feasibility pilot study was first conducted in 1993 using two groups. The **initial group** comprised 18 undergraduate science teacher trainees, and the **second group** constituted 14 graduate BEd students, both at the University of Cape Town. This study was conducted in order to measure the test/retest reliability of the instrument, to check for clarity of wording of items and to rehearse instructional procedures. The test/re-test scores of the **first group** yielded a reliability coefficient of $r = 0.80$ for the Bybee scale, and the **second group** a reliability coefficient of $r = 0.70$. The test/retest interval was one hour.

3.3 THE RESEARCH METHOD AND DATA COLLECTION PROCEDURES

The survey method is a direct way to obtain information concerning an identified topic (Keeves, 1988:107), and it is a way of gathering data at a particular point in time with the intention of describing the nature of existing conditions or determining relationships that exist between specific events (Cohen and Manion, 1994:83).

3.3.1 Data collection in 1984

For the first study, on international science educators, surveys were mailed during late April and early May, 1984. Careful attention was paid to factors contributing to high response rate in survey research. The covering letter introduced the need for the research, and indicated the complications of an international survey, as well as the potential contributions. Each letter was individually addressed and typed. Self addressed envelopes were enclosed, and those for U.S. respondents were stamped. All other respondents were given a U.S. dollar for return postage. By late May 60% of the surveys had been completed and returned. A follow-up letter was sent which resulted in another 20% response (Bybee and Mau, 1986:601).

3.3.2 Data collection in 1993

In August 1993 a biology workshop was held at Rhodes High School in Cape Town. This workshop was attended by biology and general science teachers from secondary schools situated in and around Cape Town. The workshop was divided into two sessions. The first session was scheduled for the presentation of topics on self-regulated learning in biology and environmental issues. The second session was scheduled for teachers to study the displays which students could design, with the help of their teachers, to help them understand their biology lessons better.

During the break between the two sessions the teachers, seated as an intact group, were given questionnaires, including the Bybee scale, to complete and 100% of these were collected at the end of the last session. Due to time constraints, however, some teachers could not complete the second part of the questionnaire which required them to give suggestions and recommendations on the classroom teaching of the global problems. Although this can be regarded as one of the limitations of this survey, it outweighed the problems

which would have been encountered had the responses tried to be collected by return post.

In October 1993 the chemical engineering undergraduates were surveyed as an intact group in their class. Under the direction of their lecturers, their responses were administered and collected and returned to the researcher during a normal time-tabled lecture.

At the beginning of November 1993, sixty of the surveys incorporating the unaltered Bybee scale were distributed to science educators in five teacher training colleges and five secondary schools in Transkei. This was carried out with the help of colleagues. The returns obtained were 92% of the surveys sent.

The subsidiary questionnaire was posted to lecturers in engineering by internal mail at the University of Cape Town in December 1993 (Table 3.2 page 85). The aim was to gather additional current data and suggestions for an updated version of the Bybee instrument for future surveys. Twenty responses were obtained by return internal mail, offering a wide variety of considerations and updated suggestions for future development.

The following chapter presents the findings and results of this investigation with the five surveyed samples.

CHAPTER 4

RESULTS

In this chapter the results and the summary of findings for the six hypotheses are presented.

4.1 THE EMPIRICAL FINDINGS

The previously published results obtained for the mean prioritisation of the global problems for 262 international science educators in 1983 are presented in Table 4.1 on page 39. The six most highly prioritised problems were:

World hunger and food resources; population growth; air quality and the atmosphere; water resources; war technology; human health and disease; and energy shortages.

The results obtained in 1993 in South Africa for the mean prioritisations of the global problems by 76 Cape Town science educators are presented in Table 4.2 on page 40. The six most highly prioritised global problems were found to be:

Human health and disease; population growth; world hunger and food resources; water resources; land use; and air quality and the atmosphere.

Table 4.1: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators (N=262) in 1984 (Sample 1)

Global Problem	Mean Priority Score	Rank of Relative Importance
World hunger	3.92	1
Population growth	4.35	2
Air quality	5.43	3
Water resources	5.53	4
War technology	5.80	5
Human health	5.82	6
Energy shortages	6.30	7
Land use	6.52	8
Hazardous substances	7.49	9
Extinction of plants and animals	8.37	10
Nuclear reactors	8.38	11
Mineral resources	9.40	12

Table 4.2: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators (N=76) in 1993 (Sample 2)

Global Problem	Mean Priority Score	Rank of Relative Importance
Human health	3.36	1
Population growth	3.58	2
World hunger	3.98	3
Water resources	4.62	4
Land use	6.01	5
Air quality	6.49	6
Energy shortages	7.15	7
Extinction of plants and animals	7.94	8
Hazardous substances	7.96	9
Mineral resources	8.03	10
War technology	8.84	11
Nuclear reactors	9.82	12

Table 4.3: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by University of Cape Town chemical engineering students (N=129) in 1993 (Sample 3)

Global Problem	Mean Priority Score	Rank of Relative Importance
Population growth	4.95	1
World hunger	4.96	2
Human health	4.98	3
Air quality	5.26	4
Water resources	5.38	5
Hazardous substances	5.83	6
Land use	6.47	7
Energy shortages	6.80	8
Extinction of plants and animals	7.15	9
Mineral resources	8.15	10
Nuclear reactors	8.98	11
War technology	9.20	12

Table 4.4: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Transkei science educators (N=55) in 1993 (Sample 4)

Global Problem	Mean Priority Score	Rank of Relative Importance
Population growth	5.11	1
Human health	5.13	2
Air quality	5.29	3
World hunger	5.60	4
Water resources	5.69	5
Land use	5.74	6
Hazardous substances	6.38	7
Nuclear reactors	6.40	8
War technology	7.80	9
Energy shortages	7.95	10
Extinction of plants and animals	8.07	11
Mineral resources	8.89	12

Table 4.3 on page 41 presents the results obtained for the mean prioritisations of the global problems by 129 undergraduate chemical engineers at the University of Cape Town. The six most highly prioritised global problems were:

Population growth; world hunger and food resources; human health and disease; air quality and atmosphere; water resources; and hazardous substances.

The results obtained for the mean prioritisations of the global problems by 55 Transkei science educators are presented in Table 4.4 on page 42. The six most highly prioritised global problems were:

population growth; human health and disease; air quality and the atmosphere; world hunger and food resources; and land use.

The overall conclusion drawn from these four tables of findings is that, over a ten year period, five out of six top priorities are common to all four samples, that is:

- population growth (1st, 1st, 2nd, 2nd);
- world hunger (1st, 2nd, 3rd, 4th);
- human health (1st, 2nd, 3rd, 6th);
- air quality (3rd, 3rd, 4th, 6th); and
- water resources (4th, 4th, 5th, 5th).

These findings are also depicted in Figure 4.1 on page 44. This presents the graph of Mean Priority Scores for the four samples (international science educators, Cape Town science educators, chemical undergraduate engineers of the University of Cape Town and Transkei science educators) with respect to the Global Problems incorporated into the Bybee scale.

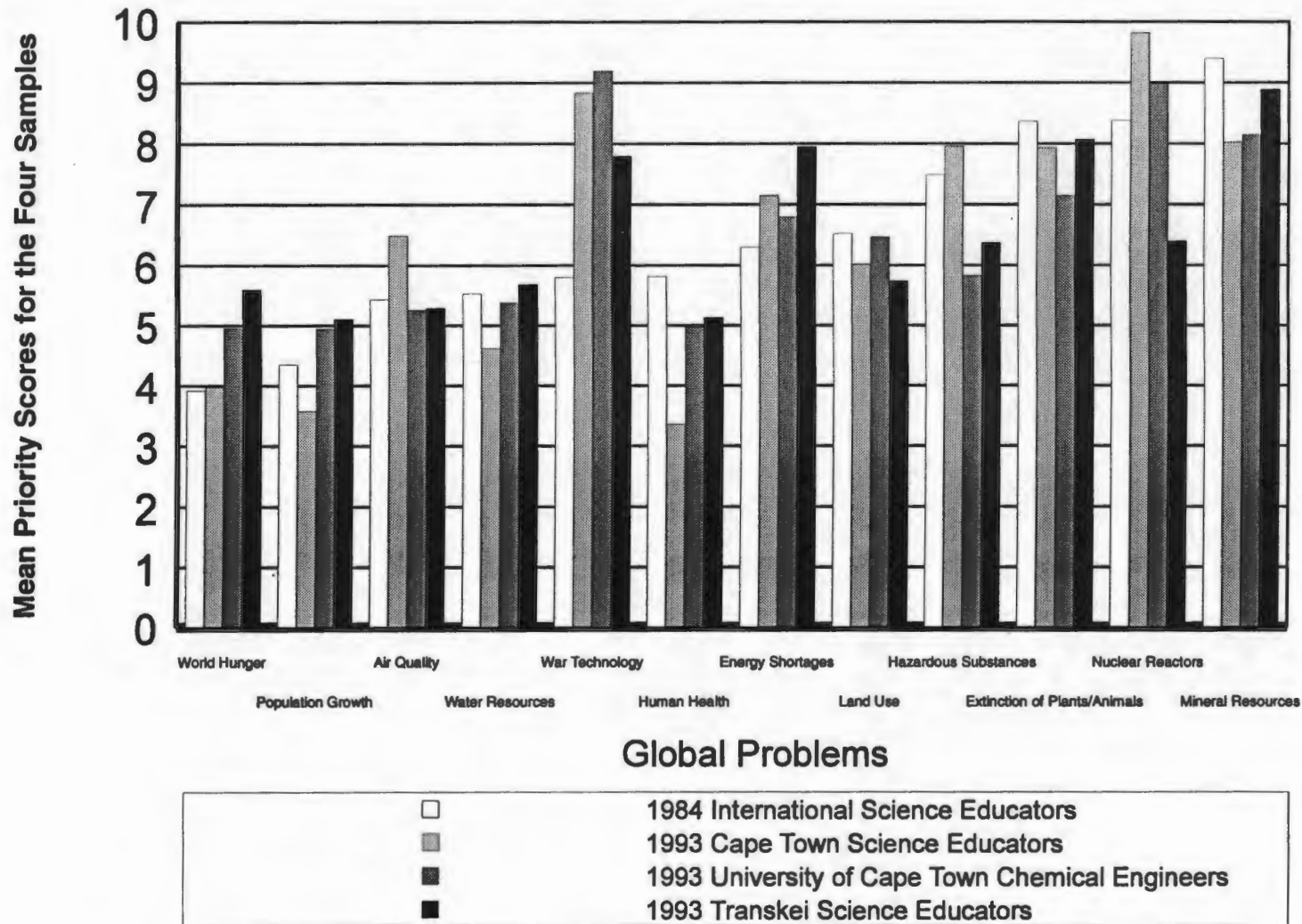


Figure 4.1: Mean Priority Scores for the Four Samples with respect to the Twelve Global Problems, incorporated into the Bybee Scale

4.2 NULL HYPOTHESES AND INTERCORRELATIONS

The above data sets can be paired and analysed by means of the Spearman's rank order correlation, used to indicate correlations between X and Y, where X represents a set of ranks for one group of subjects and Y represents another set of ranks for another group. The Spearman's rank order correlation coefficient is calculated as follows:

$$\text{rho} = 1 - \frac{6 \sum D^2}{N(N^2 - 1)}$$

where N = the size of the sample

$\sum D^2$ = sum of rank order difference squared

(Mulder, 1987:76 and Neave, 1981:40)

H₀1 There will be no statistically significant correlation between the international science educators in 1984 (N=262) and Cape Town science educators in 1993 (N=76) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Correlating the ranks in Table 4.5 on page 48, the Spearman calculation, recorded on page 54 in Table 4.11, yielded rho=0.68 (N=12) at p=0.02. Thus, the null hypothesis is rejected at the level p<0.05. (See critical values for Spearman's rank correlation coefficient in Appendix H.)

H₀2 There will be no statistically significant correlation between the international science educators (N=262) and Transkei science educators (N=55) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

There is a significant correlation between 262 international science educators and 55 Transkei science educators with regard to their mean rankings of global problems on the Bybee scale as a whole. Using the ranks in Table 4.6 the Spearman calculation, recorded in Table 4.11, yielded $\rho=0.76$, ($N=12$), with $p=0.01$. Thus the null hypothesis is rejected.

H₀3 There will be no statistically significant correlation between the international science educators ($N=262$) and the chemical engineering undergraduate students of the University of Cape Town ($N=129$) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Using the ranks in Table 4.7 on page 50 Spearman's calculation in Table 4.11, yielded $\rho=0.73$ ($N=12$), $p=0.02$, which is statistically significant at the level $p=0.05$. Thus there is a statistically significant correlation between 262 international science educators and 129 chemical engineering undergraduate students of the University of Cape Town. The null hypothesis is thus rejected.

H₀4 There will be no statistically significant correlation between the Cape Town science educators ($N=76$) and the Transkei science educators ($N=55$) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

There is a significant correlation between 76 Cape Town science educators and 55 Transkei science educators with regard to their mean rankings of global problems on the Bybee scale. Using the ranks in Table 4.8 on page 51 Spearman's calculation, recorded in Table 4.11, yielded $\rho=0.79$ ($N=12$), $p=0.009$, which is statistically significant at the level $p=0.01$. Thus the null hypothesis is rejected.

H₀5 There will be no statistically significant correlation between the Cape Town science educators (N=76) and the chemical engineering undergraduates of the University of Cape Town (N=129) with regard to their mean rankings of the twelve listed global problems of prime importance related to science and technology on the Bybee scale.

Considering the ranks in Table 4.9 on page 52 the Spearman calculation, recorded in Table 4.11, yielded $\rho=0.90$ (N=12), $p=0.003$, which is statistically highly significant at the level $p=0.01$. Therefore, there is a significant correlation between Cape Town science educators (N=76) and chemical engineering undergraduates (N=129) with regard to their mean rankings of the global problems on the Bybee scale. The null hypothesis is therefore rejected at the level $p=0.01$.

H₀6 There will be no statistically significant correlation between Transkei science educators (N=55) and chemical engineering undergraduates of the University of Cape Town (N=129) with regard to their mean rankings of the twelve global problems of prime importance related to science and technology on the Bybee scale.

Using the ranks in Table 4.10 the Spearman calculation, recorded in Table 4.11, yielded $\rho=0.87$ (N=12), $p=0.004$, which is statistically significant at the level $p=0.01$. Thus, there is a significant correlation between the 55 Transkei science educators and the 129 chemical engineering undergraduates with regard to their mean rankings of global problems on the Bybee scale. The null hypothesis is therefore rejected at the level $p=0.01$.

Table 4.5: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and Cape Town science educators in 1993

Global Problem	1984 International Science Educators N=262		1993 Cape Town Science Educators N=76	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
World hunger	3.92	1	3.98	3
Population growth	4.35	2	3.58	2
Air quality	5.43	3	6.49	6
Water resources	5.43	4	4.62	4
War technology	5.80	5	8.84	11
Human health	5.82	6	3.36	1
Energy shortages	6.30	7	7.15	7
Land use	6.52	8	6.01	5
Hazardous substances	7.49	9	7.96	9
Extinction of plants and animals	8.37	10	7.94	8
Nuclear reactors	8.38	11	9.82	12
Mineral resources	9.40	12	8.03	1

Table 4.6: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and Transkei science educators in 1993

Global Problem	1984 International Science Educators N=262		1993 Transkei Science Educators N=55	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
World hunger	3.92	1	5.60	4
Population growth	4.35	2	5.11	1
Air quality	5.43	3	5.29	3
Water resources	5.43	4	5.69	5
War technology	5.80	5	7.80	9
Human health	5.82	6	5.13	2
Energy shortages	6.30	7	7.95	10
Land use	6.52	8	5.74	6
Hazardous substances	7.49	9	6.38	7
Extinction of plants and animals	8.37	10	8.07	11
Nuclear reactors	8.38	11	6.40	8
Mineral resources	9.40	12	8.89	12

Table 4.7: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by international science educators in 1984 and undergraduate chemical engineers in 1993

Global Problem	1984 International Science Educators N=262		1993 Undergraduate Chemical Engineers N=129	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
World hunger	3.92	1	4.96	2
Population growth	4.35	2	4.95	1
Air quality	5.43	3	5.26	4
Water resources	5.43	4	5.38	5
War technology	5.80	5	9.20	12
Human health	5.82	6	4.98	3
Energy shortages	6.30	7	6.80	8
Land use	6.52	8	6.47	7
Hazardous substances	7.49	9	5.83	6
Extinction of plants and animals	8.37	10	7.15	9
Nuclear reactors	8.38	11	8.98	11
Mineral resources	9.40	12	8.15	10

Table 4.8: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators in 1993 and Transkei science educators in 1993

Global Problem	1993 Cape Town Science Educators N=76		1993 Transkei Science Educators N=55	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
Human health	3.36	1	5.13	2
Population growth	3.58	2	5.11	1
World hunger	3.98	3	5.60	4
Water resources	4.62	4	5.69	5
Land use	6.01	5	5.74	6
Air quality	6.49	6	5.29	3
Energy shortages	7.15	7	7.95	10
Extinction of plants and animals	7.94	8	8.07	11
Hazardous substances	7.96	9	6.38	7
Mineral resources	8.03	10	8.89	12
War technology	8.84	11	7.80	9
Nuclear reactors	9.82	12	6.40	8

Table 4.9: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Cape Town science educators in 1993 and undergraduate chemical engineers in 1993

Global Problem	1993 Cape town Science Educators		1993 Undergraduate Chemical Engineers	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
Human health	3.36	1	4.98	3
Population growth	3.58	2	4.95	1
World hunger	3.98	3	4.96	2
Water resources	4.62	4	5.38	5
Land use	6.01	5	6.47	7
Air quality	6.49	6	5.26	4
Energy shortages	7.15	7	6.80	8
Extinction of plants and animals	7.94	8	7.15	9
Hazardous substances	7.96	9	5.83	6
Mineral resources	8.03	10	8.15	10
War technology	8.84	11	9.20	12
Nuclear reactors	9.82	12	8.98	11

Table 4.10: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by Transkei science educators in 1993 and undergraduate chemical engineers in 1993

Global Problem	1993 Transkei Science Educators		1993 Undergraduate Chemical Engineers	
	Mean Priority Score	Rank of Relative Importance	Mean Priority Score	Rank of Relative Importance
Population growth	5.11	1	4.95	1
Human health	5.13	2	4.98	3
Air quality	5.29	3	5.26	4
World hunger	5.60	4	4.96	2
Water resources	5.69	5	5.38	5
Land use	5.74	6	6.47	7
Hazardous substances	6.38	7	5.83	6
Nuclear reactors	6.40	8	8.98	11
War technology	7.80	9	9.20	12
Energy Shortages	7.95	10	6.80	8
Extinction of plants and animals	8.07	11	7.15	9
Minerals resources	8.89	12	8.15	10

Table 4.11: Spearman's rank correlations

SAMPLES OF RESPONDENTS				
Samples	1	2	3	4
1	1.0000	0.6783*	0.7273*	0.7552*
	(12)	(12)	(12)	(12)
2	1.0000	0.0245	0.0159	0.0122
	0.6783*	1.0000	0.9021**	0.7902**
3	(12)	(12)	(12)	(12)
	0.0245	1.0000	0.0028	0.0088
4	0.7273*	0.9021**	1.0000	0.8671**
	(12)	(12)	(12)	(12)
4	0.0159	0.0028	1.0000	0.0040
	0.7552*	0.7902**	0.8671**	1.0000
4	(12)	(12)	(12)	(12)
	0.0122	0.0088	0.0040	1.0000

Key: coefficient
 (item sample size)
 significance level

Sample 1 International Science Educators
 Sample 2 Cape Town Science Educators
 Sample 3 Undergraduate Chemical Engineers at the University
 of Cape Town
 Sample 4 Transkei Science Educators

* Significant $p < 0.05$

** Significant $p < 0.01$

4.3 PRESENTATION OF THE QUALITATIVE FINDINGS

4.3.1 *The following list of suggestions is a combined summary of the open-ended recommendations made by some of the 131 Cape Town and Transkei science educators who responded to the second part of the questionnaire.*

Photocopies of the more detailed aspects of the suggestions made by the respondents are included in Appendix I.

1. Students should be made more aware of these global problems, and this might be done by incorporating these into the school curriculum.

This suggestion was advocated by 34 science educators.

2. A core curriculum which includes environmental education should be offered to all students, irrespective of their intended careers.

This recommendation was made by 28 respondents.

3. Pupils should be engaged in practical projects, such as cans, bottles, or plastic collection, which might help to minimise or eliminate these problems (20 respondents). They could also watch relevant video programmes (19 respondents), read supplementary journals (04 respondents) and attend seminars which emphasise environmental conservation and protection (26 respondents).

4. Pupils should be taught about family planning and be cautioned about the problems they face when engaged in sexual relations.

This suggestion was made by 27 teachers.

5. Community based programmes such as tree planting and water conservation were recommended by 19 respondents in order to promote a growing awareness, among community members, of these global problems.
6. Thirty five science educators stated that it was difficult for them to rank the problems accurately because of their close interrelatedness. Therefore, pupils should also be made aware of this mutual interdependence of natural and human systems.

4.3.2 *Additional, more up-to-date priorities and issues singled out by individuals in the follow-up sample of 20 lecturers in the Faculty of Engineering at the University of Cape Town in 1993 included:*

The provision of mass housing and infrastructure, sanitation, job creation, the abuse of high technology in communications, technological illiteracy among decision-makers, abuse and reduction of oceanic resources, photochemical smog, the prediction and possible control of droughts and floods, the demands on the human race of the information explosion, electromagnetic wave hazards and pollution, resource depletion, education and the dissemination of knowledge, the emergence and separation of C.P. Snow's 'Two Cultures' and the myth of the peace dividend.

Urbanisation was described as a many-faceted problem encompassing sociology, systems engineering, water supply, waste water treatment and land use.

The abuse of high technology in communications was mentioned as encompassing global indoctrination of the masses by television; the creation of hybrid bioelectric systems; genetic engineering devoid of an understanding of the role that chaos plays in ensuring the survival of life; and the proliferation of doubtful information by satellite.

The depletion of oceanic resources was said to be manifested in overfishing, pollution, rising sea levels, and the effects of the ability of the oceans to absorb more carbon dioxide.

The effects of microwaves on humans and animals were also singled out as causes of concern.

The myth of the peace dividend was that even though less money is being spent on armaments, the savings are not going into new technology to solve the problem. This concern is to be addressed in evolving engineering curricula.

Appendix J documents the suggestions made by lecturers in the Faculty of Engineering at the University of Cape Town.

The next chapter will explain and discuss these findings, and will offer a critique of the research study and the instrument used.

CHAPTER 5

DISCUSSION

5.1 DISCUSSION OF THE EMPIRICAL FINDINGS

The significantly high correlations among the four samples reflect a large degree of consistency over the same set of issues implying that, even after ten years, environmental scientists still have not arrived at the needed large scale practical solutions. Prioritisation of the top six global problems in 1993 yields a close match with the same global problems highly prioritised in 1984.

However, some changes occur in individual rank order. This may or may not occur as a consequence of deviations resulting from small size sampling. There is one exceptional item in each sample's mean ranking, such as war technology in the case of the international science educators, hazardous substances in the case of chemical engineering undergraduates students and land use in the case of both the Cape Town science educators and Transkei science educators.

This study also shows that, among the top ranked items over a ten year period, the most highly prioritised global problems remain population growth; world hunger and food resources; human health and disease; air quality and the atmosphere; and water resources across all four samples (see Table 5.1 on page 59).

Table 5.1: The mean priority scores, and ranks of relative importance, of twelve global problems in science and technology rated by four samples of science educators/engineers over a ten year period

<i>Global problem</i>	1984 International Science Educators N=262		1993 Cape Town Science Educators N=76		1993 University of Cape Town Chemical Engineers N=129		1993 Transkei Science Educators N=55	
	<i>Mean priority score</i>	<i>Rank of relative importance</i>	<i>Mean priority score</i>	<i>Rank of relative importance</i>	<i>Mean priority score</i>	<i>Rank of relative importance</i>	<i>Mean priority score</i>	<i>Rank of relative importance</i>
World hunger	3.92	1	3.98	3	4.96	2	5.60	4
Population growth	4.35	2	3.58	2	4.95	1	5.11	1
Air quality	5.43	3	6.49	6	5.26	4	5.29	3
Water resources	5.53	4	4.62	4	5.38	5	5.69	5
War technology	5.80	5	8.84	11	9.20	12	7.80	9
Human health	5.82	6	3.36	1	4.98	3	5.13	2
Energy shortages	6.30	7	7.15	7	6.80	8	7.95	10
Land use	6.52	8	6.01	5	6.47	7	5.74	6
Hazardous substances	7.49	9	7.96	9	5.83	6	6.38	7
Extinction of plants-animals	8.37	10	7.94	8	7.15	9	8.07	11
Nuclear reactors	8.38	11	9.82	12	8.98	11	6.40	8
Mineral resources	9.40	12	8.03	10	8.15	10	8.89	12

These top ranked items clearly relate to the basic human needs for long term survival (health, air, food and water); and the findings of this small scale Cape Town and Transkei study offer clear and consistent empirical support and preliminary justification for the inclusion of section 20 of Chapter 4 in the Government White Paper on Education and Training of the 15th of March 1995, which says:

Environmental education, involving an interdisciplinary, integrated and active approach to learning, must be a vital element of all levels and programmes of the education and training system, in order to create environmentally literate and active citizens and ensure that all South Africans, present and future, enjoy a decent quality of life through the sustainable use of resources (page 22).

Thus the statistical findings presented in this investigation substantiate the direction being taken by the new South African Government of National Unity's RDP in its planning policies for the future of science and technological education.

The higher ranking of hazardous substances by the chemical engineering undergraduate students indicates their awareness of the importance of this problem to human health. It provides evidence in support of claims for the importance, stability and relevance of modern curricula in chemical engineering, for example, as reproduced in Appendix G (University of Cape Town Chemical Engineering syllabus from the 1995 Faculty Handbook). In 1995, at the University of Cape Town, more than half the students take an optional course on Environmental Process Engineering, which appears to be reflected in the data gathered on their prioritisation (Appendix G).

Population growth, with first and second rankings, suggests a common human concern which links the above mentioned problems. This supports one of the issues identified by Tergart (1994:19) when he visited the Foundation for Research and Development. He stated that major environmental and social problems of this country (South Africa) occur as a result of rapid population growth caused by the natural increase, and immigration coupled with a

dramatic movement from rural to urban areas. This factor, he claims, poses a problem to health, as it places increased strain on the provision of clean water supplies; adequate sanitation; appropriate housing and medical services; and quality of life.

At the end of the ten year period spanned by this study, war technology has been appreciably de-ranked – from its fifth position initially designated in 1984 by 262 international science educators – to the consistent ninth, eleventh and twelfth positions assigned by Transkei science educators, Cape Town science educators and undergraduate chemical engineers at the University of Cape Town in 1993.

This change in position might be attributed to the agreed strategic arms limitations of the former USSR and the United States of America which, at this point in time, do not seem to threaten the Republic of South Africa.

This trend is also in harmony with the announcement made by Deputy President Thabo Mbeki (Cape Times, Business Report, September 7, 1995:17), when he reported that it was gratifying to see South Africa protesting against France's nuclear weapons testing at Mururoa in the South Pacific (Cape Times, September 6, 1995) as this was a violation of the Nuclear Non-Proliferation Treaty.

Consistency in the rise in position of human health, during the last decade, from the sixth to the first, second and third positions might be attributed to a more widespread awareness of the spread of incurable and fatal diseases in Africa such as AIDS, and to an increase in the incidence of skin cancers associated with the depletion of the ozone layer mainly caused by the use of chlorofluorocarbons (CFCs). For example, a ban on the use of CFCs was announced recently (SAFM, News Bulletin, August 17, 1995).

This was a sequel to an international plan of action for a world-wide curb on CFCs, which was signed in 1987 by a number of countries in Montreal, excluding South Africa, which signed later, in January 1990 (Clarke, 1991:61).

The change in position of land use from the eighth rank assigned by international science educators to the fifth and the sixth position by Cape Town science educators and Transkei science educators might be ascribed to a regional concern for the common destruction of African life-support systems through the over-exploitation of resources.

Local biology textbooks and syllabi refer to the common practice of veld-burning, the chopping down of trees for firewood, and inappropriate farming methods. These often lead to problems such as soil erosion, deforestation and desertification which, accumulatively, tend to threaten human survival in Southern Africa.

These findings also show that African perceptions of basic human priorities are not unique to Africa, but that science educators in other continents appear to share similar major or universal concerns, but with some variations in priorities, depending on local context.

Preliminary findings which have emanated from this study may be useful to South African curriculum developers who have a task of implementing section 16, 17, and 20 on page 27 and section 30 on page 28 of the 15 March 1995 White Paper on Education and Training, where sections 16, 17, and 20 explicitly state that the Ministry of Education is fully "committed to a participatory process of curriculum development and trialling", and it does "recognise the importance of setting up processes for the production of the new curriculum frameworks and core curricula".

It has also been mentioned that "the development of these new curriculum frameworks and core curriculum" could bring about the formulation of "new national norms and standards" which could enable the provincial Departments of Education in expressing their "interests and priorities".

The above mentioned sections, for example, link-up with the findings that a core syllabus might cater for interests that are nationally important, and options could be more relevant to regional or cultural values and their respective priorities.

Section 30 made mention of the Ministry of Education's intention to explore a "holistic and an integrated approach" which recognises issues of "health; social; psychological; academic and vocational" development, which correlates with the inter-disciplinary, integrated and active approach through which the global STS problems might be introduced into the school curricula.

Different ranges have been recorded between the lowest and the highest mean priority scores within each sample. In Table 4.1 the mean priority scores range from 3.92 to 9.4, resulting in a range of 5.48; in Table 4.2 the mean priority scores range from 3.36 to 9.82, resulting in a range of 6.46; in Table 4.3 the mean priority scores range from 4.95 to 9.20, the resulting range being 4.25; and in Table 4.4 the mean priority scores range from 5.11 to 8.89 resulting in a range of 3.78. The different ranges are clearly shown by Figure 4.1 on page 44, and are summarised by Figure 5.1 on page 64.

Comparing these four spreads, Cape Town science educators' mean priority scores cover the widest range, followed by the international science educators, the chemical engineering undergraduates, and the smallest range occurs for the Transkei science educators' mean priority scores.

Possible reasons for the difference in these spreads are speculative. For example, the wider spread in the case of Cape Town science educators might be ascribed to there being diverse local problems which strongly affect some individual teachers more than the others; whereas in the case of Transkei science educators, most of these problems tend to be perceived more or less of equal concern to the community, hence their mean priority scores have a smaller range.

However, these possible explanations remain mere speculations, since the purpose of this study was neither intended nor extended to interviewing the various respondents. This could be included in future studies.

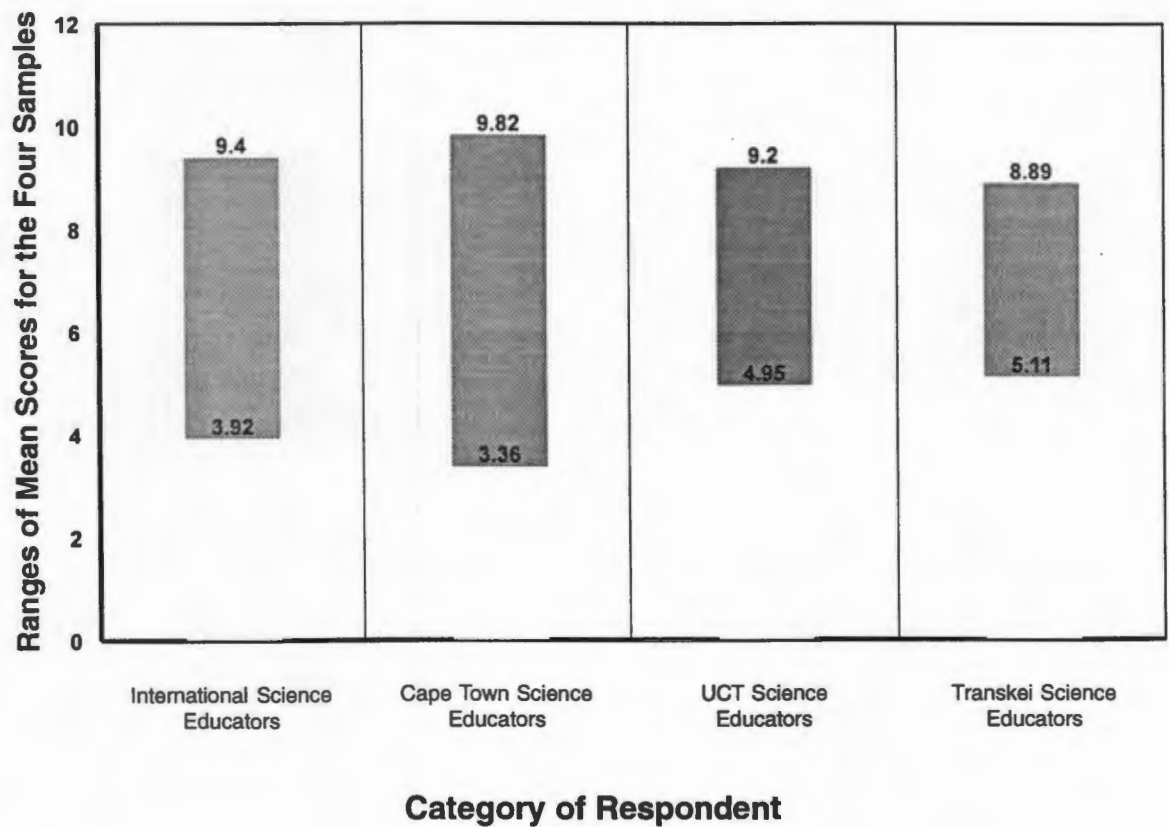


Figure 5.1: Ranges of Mean Priority Scores for the Four Samples for Twelve Global Problems

5.2 DISCUSSION OF THE RESEARCH METHOD

A survey is an appropriate research method for gathering data in this kind of research, but there were shortcomings in the survey of the Cape Town science educators, such as the limited time of ten minutes available for careful and considered completion of the second section of the survey in August 1993.

About 40% of the science educators in Cape Town could not complete the second part of the questionnaire within the allocated time which required them to make recommendations about the teaching of these global problems. Had the respondents been allowed to take home the questionnaires, however, some may not have returned the responses and others could have delayed them.

It was felt best to use data obtained from a captive, intact sample in the available time, since all the respondents were able to complete the essential first section, i.e. the Bybee Scale.

5.3 CRITIQUE ON THE INSTRUMENT ITSELF

In 1993 some questions could not be dealt with satisfactorily through the use of a 1984 survey instrument (the Bybee scale). Some related items were perceived as implicit in broader items, such as several mentioned by the twenty respondents from the Faculty of Engineering at the University of Cape Town. For example, mass housing; sanitation; job creation; and resource depletion might have been included under mineral resources, according to some respondents' perceptions.

There was also urbanisation which some respondents felt strongly could have been included in a separate category rather than being incorporated under land use, as it is a major problem which encompasses sociology, systems-engineering, water supply, waste water treatment and many other issues.

Other aspects on which data might be collected in the future use of the second part of this instrument are:

- whether respondents foresee any improvements or deterioration in these global problems by the year 2000;
- how much respondents actually know about the global problems, and the sources of their information;
- how many of the global problems should be taught at school;
- at which school level these problems could be introduced; and
- whether or not an understanding of these problems should be examined in matriculation and, if so, what form the test questions might take.

Thus, in the light of these developments, my provisional suggestion for a 1994 updated version of the Bybee instrument (modified) is presented for consideration, in Table 5.2 in Appendix K.

A Xhosa-version of Table 5.2, translated in 1995, is attached in Appendix K.

The last chapter will give final conclusions, address some applications of the findings, and propose recommendations for further research.

CHAPTER 6

CONCLUSIONS, IMPLICATIONS AND RECOMMENDATIONS

6.1 CONCLUSIONS

This study has supported and documented linkages between science-and-technology-related issues and education. It has further developed a global perspective for the science education community. Science educators and engineers are a crucial link between science, education and their society's needs and aspirations.

Using this theme of global problems related to science and technology, the importance of a science-technology-society instructional strategy – currently being initiated in the South African schools syllabi – has been documented in preliminary studies with relatively small samples compared to the school and university populations as a whole.

6.2 IMPLICATIONS

The findings presented in this study have a number of possible implications for the teaching of global problems:

- Education in South Africa appears to be a major channel through which students could be made aware of the global problems facing humankind which are related to science and technology.
- Some science educators stated that it was difficult for them to rank the problems because of their interrelatedness; therefore students should be made aware of this mutual interdependence of natural and human systems.

- Problems of a universal nature should be studied by all students, irrespective of their individual future careers.

- As there was almost no substantial change in mean ranks over a period of ten years (except for war technology) it is possible that by the year 2000 these problems might still prevail. Thus priority practical actions need to be considered to combat these problems, like the projects conducted by:
 - (1) The National Association for Clean Air (NACA);
 - (2) Solid Waste Management practised in the city of Johannesburg;
 - (3) Africa Tree Centre; Abalimi Bezekhaya; Khayelitsha Environmental Action Group (Khan, 1991:104);
 - (4) Wilderness Leadership Schools in Cape Town and Natal; etc.

6.3 SUGGESTED RECOMMENDATIONS

Recommendation 1

There is a need for the infusion of environmental education into the formal school core curriculum, running from primary to secondary education. Options can occur at the tertiary level. A curriculum framework for this has already been proposed (see Chapter 2, sub-section 2.2.5 on page 23).

Recommendation 2

An integrated science curriculum could also be considered along with curriculum frameworks outlined by the Centre for Education Policy Development (1995) in its discussion document, which are in line with the aims proposed for science and technology by the ANC Discussion Document on Education Policy (ANC, 1994b).

Recommendation 3

This integrated curriculum could aim at making the students aware of the current problems facing humans in South Africa which are related to science and technology.

Recommendation 4

Students should be encouraged to participate in projects which could reduce or eliminate the above mentioned problems. Teaching strategies and techniques might include technology competitions, guest science speakers, journals, environmental debates, video conservation programmes, and seminars which stress environmental conservation and protection.

Recommendation 5

Money spent on nuclear arms (The Argus, Tuesday April 19, 1994:3 and Cape Times, Thursday April 21, 1994:7) could be partially redirected towards the amelioration of basic human needs like the provision of food, housing, health services and water services.

Recommendation 6

Students could be involved in projects which combat or prevent diseases like AIDS, skin cancer, cholera and others of regional relevance. They could also be taught about family planning or abstinence from sex, as in the case of a talk by Dr E. Kok, at the University of Natal, on 'abstinence education' where he pointed out the importance of "abstinence outside marriage, faithfulness, monogamous relationships, and lifelong commitment' (Weekend Argus, April 16/17, 1994:10). This might assist in the reduction of the high population growth rate which gives rise to problems such as poverty, poor housing facilities, etc.

Recommendation 7

Community based activities, which could highlight these problems and possible solutions to community members, are also recommended. These include the

First-Aid projects; AIDS education; and health workshops and clinics which are currently in operation in the rural and urban areas.

6.4 CONSIDERATIONS WITH REGARD TO SCIENCE EDUCATION POLICY

Since this study has been confined mainly to the prioritisation of the global problems incorporated into the Bybee scale, there are a number of issues which have arisen from the literature review of this study pertaining to science education policy which might be considered for further research. These can be summarised as follows:

Recommendation 8

Science teachers in schools could encourage pupils to understand and deal with the increasing threat and damage to their environment.

Recommendation 9

Schools could motivate pupils to participate and use their knowledge in revitalising and restoring their environment.

Recommendation 10

Currently, teachers do not always reflect the kind of science which is based on the interests of their pupils, and these may differ from one region to the other. Future plans to reduce this problem could be considered.

Recommendation 11

The science curriculum which in the past has been fragmented and compartmentalised could be structured, and its teaching be organised, so as to give insights into the ecological and environmental impact of technology in modern society, and instil in the young a feeling of social responsibility.

Recommendation 12

Decision-makers could implement policies which maintain balance between economic growth and environmental sustainability.

Recommendation 13

Cooperative links could be forged between the government, industrialists and academia to prepare future citizens who understand the world of research development.

Recommendation 14

Teacher education could play a role in preparing teachers who are environmentally literate.

Recommendation 15

The new Government of National Unity could prepare plans to redress the imbalances which came about as a result of the former apartheid policies which have led to the degradation of our environmental resources.

6.5 RECOMMENDATIONS FOR FURTHER RESEARCH**Recommendation 16**

For those respondents who might not object to being known for the purposes of in-depth interviews, names or even codes and addresses could be requested in further studies.

Recommendation 17

More responses could be invited from the various regions of the New South Africa, in order to establish whether there will be a change in the prioritisation of these global problems in future.

Recommendation 18

High school students can also be included in surveys to determine how much they know about these global problems and how many of them are taught at school.

Recommendation 19

Suggestions which were given by the twenty lecturers from the Faculty of Engineering at the University of Cape Town could also be included in further studies.

Whilst there are limitations in this survey, the findings obtained do provide useful data for the continued support of the science-technology-society theme in science education.

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APPENDIX A:

**College students' ranking of 12 science-
related social problems in 1984**

Problem	Rank	Mean
Air quality and atmosphere (acid rain, CO ₂ , depletion of ozone, global warming)	1	4.92
World hunger and food resources (food production, agriculture, cropland conservation)	2	5.06
War technology (nerve gas, nuclear development, nuclear arms threat)	3	5.42
Hazardous substances (waste dumps, toxic chemicals, lead paints)	4	6.21
Energy shortages (synthetic fuels, solar power, fossil fuels, conservation, oil production)	5	6.29
Population growth (world population, immigration, carrying capacity, foresight capability)	6	6.36
Water resources (waste disposal, estuaries, supply, distribution, ground water contamination, fertiliser contamination)	6	6.36
Land use (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification)	8	6.51
Human health and disease (infectious and non-infectious disease, stress, diet and nutrition, exercise, mental health)	9	7.12
Extinction of plants and animals (reducing genetic diversity)	10	7.53
Nuclear reactors (nuclear waste managements, breeder reactors, cost of construction, safety)	11	8.05
Mineral resources (non-fuel minerals, metallic and non-metallic minerals, mining, technology, low grade deposits, recycling re-use)	12	9.03

(After Bybee and Mau, 1986:444)

Table 1.1: Ranking of science and technology related global problems, after Bybee & Mau (1986:604)

What do you see as the most important global problems related to science and technology? Rank the following 1 to 12 (with 1 indicating your top priority). Insert your numbers in the appropriate brackets.

GLOBAL PROBLEM

- [] HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals, lead paints)
 - [] HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress; noise, diet and nutrition, exercise, mental health)
 - [] MINERAL RESOURCES (non fuel minerals, metallic and non-metallic minerals, mining, technology, low-grade deposits, recycling, refuse)
 - [] WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertilizer contamination)
 - [] POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability)
 - [] EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity, wildlife protection)
 - [] ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production)
 - [] WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear arms threat)
 - [] AIR QUALITY AND ATMOSPHERE (acid rain, CO₂, depletion of ozone, global warming)
 - [] WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation)
 - [] LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, salinisation)
 - [] NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, terrorism)
-

Table 3.2: Open-ended follow-up questionnaire given to lecturers in the Faculty of Engineering at the University of Cape Town

SCIENCE AND TECHNOLOGY-RELATED GLOBAL PROBLEMS AS PERCEIVED BY UNIVERSITY OF CAPE TOWN ENGINEERS IN 1993

To assist us to complete a series of published surveys conducted over ten years, would you be kind enough to peruse the following twelve global problems. During the last decade, they have been considered to be the most important global problems affecting the human race in the area of science and technology.

In the spaces provided below the list, please name any other global problems which you consider, as an engineer, to be of worldwide paramount importance in 1993.

Kindly post your response back by internal mail to:

Professor K. Rochford
Science Education Unit
School of Education

by the end of the first week in December. The findings will be disseminated in the Faculty of Engineering in 1994, together with the findings derived from large samples of other groups during the last decade.

GLOBAL PROBLEM

HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals, lead paints).

HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress, noise, diet and nutrition, exercise, mental health).

MINERAL RESOURCES (non-fuel minerals, metallic and non-metallic minerals, mining technology, low grade deposits, recycling, refuse).

WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertiliser contamination).

POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability).

EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity, wildlife protection).

ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production).

WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear arms threat).

AIR QUALITY AND ATMOSPHERE (acid rain, carbon dioxide, depletion of ozone, global warming).

WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation).

LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, salinisation).

NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, terrorism).

Additional major global problems in science and technology:

[] _____

[] No further responses from you are suggested.
Thank you very much.
C.B. Ndodana

APPENDIX B:

Offprint of previously published work

Engineering Students' and Science Educators' Rankings of Science and Technology Related Global Problems*

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Using 262 acknowledged science educators from 41 countries, Bybee developed a scale for measuring the ranked priorities of scientists, and others, with respect to 12 major global problems related to science and technology in 1984. In 1993 this scale was readministered to samples of 129 undergraduate chemical engineering students at the University of Cape Town and to 76 Cape Town science educators. High intercorrelations were obtained among the three samples' mean ranked priorities on the scale as a whole, over the 10-year period. Among the top six global problems in 1984, five received consistently high overall prioritization in 1993, namely population growth; world hunger and food resources; human health and disease; air quality and atmosphere; and water resources. The mean ranking of war technology as a priority declined by seven places. Important goals and issues singled out by individuals in a follow-up sample of 20 lecturers in engineering at the University of Cape Town in 1993 included the provision of mass housing and infrastructure, sanitation, urbanization, job creation, the abuse of high technology in communications, technological illiteracy among decision-makers, abuse and reduction of oceanic resources, photochemical smog, the prediction and possible control of droughts and floods, demands on the human race of the information explosion, electromagnetic wave hazards and pollution, resource depletion, education and the dissemination of knowledge, the emergence and separation of C. P. Snow's 'Two Cultures' and the myth of the peace dividend.

INTRODUCTION

RECENTLY, a new program has been developed at the undergraduate level at the New Jersey Institute of Technology (NJIT) for chemical engineering students through the collaborative efforts of three faculties, namely Chemical Engineering; Humanities; and Science, Technology, and Society (STS) [1]. One of the goals of this program is to foster independent thought, a sense of cultural and intellectual breadth, and an awareness of ethical issues. In the senior courses, emphasis is on the importance of applying scientific principles to *identifying and solving problems* such as conservation and environmental control [1].

Many engineering problems are global in concept but local in solution [2, 3]. Regional environmental problems provide good illustrations. Specific examples are: actions involving rainforests in Brazil affecting global warming; power plant emissions; US automobile emissions; and mitigating hazardous waste at a planned industrial park [1, 3].

Modern engineers have a multidimensional task in society. Their work involves meeting major human needs, including sustainable development and environmental protection; designing and solving problems in real situations; anticipating health effects; and many others [1, 4, 5].

It is in this context that the Bybee scale is a useful, convenient and appropriate instrument for measuring ranked priorities of engineers and other groups of scientists with respect to 12 of the most important recognized major global problems related to science and technology [6].

BACKGROUND

This study is an enlargement and corroboration of the consistency of the findings with a sample of 262 surveyed international science educators reported by Bybee and Mau [6], and by Bybee and Najafi [7] with a sample of 317 surveyed college science students. No similar studies, however, appear to have been carried out with samples of undergraduate engineering students.

* Paper accepted 16 January 1994.

OBJECTIVES

The aim of the research is to determine:

1. which global STS problems remain highly prioritized in 1993 compared with earlier prioritizations made in 1984; and
2. the significance of high rank-order correlations occurring among samples of engineering undergraduates, international science educators and Cape Town science educators on the Bybee scale.

CLARIFICATION OF TERMS

- *Chemical engineering* is that professional field which applies chemical and physical understanding to the manufacture of materials, fuels, pharmaceuticals, chemicals, fertilizers and foods that together enhance the quality of life [8].
- *Science-technology-society (STS)* is the term applied to the latest effort to provide a real-world context for the study of science, and for the pursuit of science itself. It focuses upon current issues and attempts at their resolution as the best way of preparing people for current and future citizenship roles [9].
- *Global problems* related to science and technology, as determined in 1984 by acknowledged science educators from 41 countries, are defined in the instrument used for the data collection [6], presented in Table 1.

PROCEDURE

Selection of the instrument

A 12-item instrument developed by Bybee for use with scientists [10], citizens [11], college students [7] and science teachers [12] was used for data collection. A Cape Town pilot study was conducted with a sample of 18 undergraduates in order to determine the test/retest reliability of the instrument. This yielded a reliability coefficient of $r = 0.80$ when the intact sample was retested with the same instrument after an interval of one hour. Bybee's instrument was originally developed and refined using 262 acknowledged science educators from 41 countries [6]. For the purpose of this study that original group in 1984 will be designated as sample 1.

Data collection in 1993

Sample 2 comprised 76 Cape Town science educators surveyed as an intact group in August 1993. Sample 3 consisted of 129 undergraduate chemical engineering students of the University of Cape Town, with the data collected in October 1993 from classes of students in years 2-4 being combined into a whole. Sample 4 comprised 20 lecturers in engineering at the University of Cape Town who responded to an open-ended follow-up questionnaire in December 1993.

Table 1. Ranking of science and technology related global problems

What do you see as the most important global problems related to science and technology? Rank the following from 1 to 12 (with 1 indicating your top priority). Insert your numbers in the appropriate brackets.

GLOBAL PROBLEM

- [] HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals, lead paints)
- [] HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress, noise, diet and nutrition, exercise, mental health)
- [] MINERAL RESOURCES (non fuel minerals, metallic and non-metallic minerals, mining, technology, low-grade deposits, recycling, refuse)
- [] WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertilizer contamination)
- [] POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability)
- [] EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity, wildlife protection)
- [] ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production)
- [] WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear arms threat)
- [] AIR QUALITY AND ATMOSPHERE (acid rain, CO₂, depletion of ozone, global warming)
- [] WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation)
- [] LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, salinization)
- [] NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, terrorism)

RESULTS AND FINDINGS (see Table 2)

It was found that the rank-order correlation between the 1993 engineering undergraduates' priorities and the 1984 international science educators' priorities was 0.65. Between the 1993 engineering undergraduates' ratings and the 1993 Cape Town science educators' ratings, the correlation is 0.85. These are significantly high correlations reflecting a large degree of consistency over a 10-year period on the same set of issues.

Prioritization of the first six global problems in 1993 indicates a close match with the same global problems prioritized in 1984. However, individual changes in rank-order occur. There is, however, one exceptional item in each sample's ranking, namely *war technology* in the case of the international science educators; *hazardous substances* in the case of engineering undergraduates; and *land use* in the case of Cape Town science educators.

Priorities singled out by individuals in the follow-up sample of 20 lecturers in the Faculty of Engineering at the University of Cape Town in 1993 included the provision of mass housing and infrastructure, sanitation, urbanization, job creation, the abuse of high technology in communications, technological illiteracy among decision-makers, abuse and reduction of oceanic resources, photochemical smog, the prediction and possible control of droughts and floods, the demands on the human race of the information explosion, electromagnetic wave hazards and pollution, resource depletion, education and the dissemination of knowledge, the emergence and separation of C. P. Snow's 'Two Cultures' and the myth of the peace dividend.

Urbanization was described as a many-faceted problem encompassing sociology, systems engineering, water supply, waste water treatment and land use.

The abuse of high technology in communications was mentioned as encompassing global indoctrination of the masses by television; the creation of hybrid bioelectric systems; genetic engineering devoid of an understanding of the role that chaos plays in ensuring the survival of life; and the proliferation of doubtful information by satellite.

The depletion of oceanic resources was said to be manifested in overfishing, pollution, rising sea levels, and the effects of the ability of the oceans to absorb more carbon dioxide.

The effects of microwaves on humans and animals were also singled out as causes of concern.

The myth of the peace dividend was that even though less money is now being spent on armaments, the savings are *not* going into new technology to solve the problem. This concern is to be addressed in evolving engineering curricula.

DISCUSSION AND CONCLUSIONS

This study has shown that among the top-ranked items, over a 10-year period, the most important global problems remain population growth; world hunger and food resources; human health and disease; air quality and atmosphere; and water resources. These top-ranked items clearly relate to basic human needs for long-term survival (health, air, food and water) and provide evidence to support the importance, stability and relevance of modern curricula in chemical engineering. Population growth, with first and second rankings, suggests a common concern which links the above-mentioned problems directly or indirectly.

The higher ranking of the hazardous substances by the chemical engineering students indicates their awareness of the importance of this problem to human health. Currently, at the University of Cape Town, more than half of the third-year

Table 2. The mean priority scores, and ranks of relative importance, of 12 global problems in science and technology rated by three samples of science educators/engineers over a 10-year period

Global problem	1984 international science educators <i>n</i> = 262		1993 Cape Town science educators <i>n</i> = 76		1993 University of Cape Town chemical engineers <i>n</i> = 129	
	Mean priority score	Rank of relative importance	Mean priority score	Rank of relative importance	Mean priority score	Rank of relative importance
World hunger	3.92	1	3.98	3	4.96	2
Population growth	4.35	2	3.58	2	4.95	1
Air quality	5.43	3	6.49	6	5.26	4
Water resources	5.53	4	4.62	4	5.38	5
War technology	5.80	5	8.84	11	9.20	12
Human health	5.82	6	3.36	1	4.98	3
Energy shortages	6.30	7	7.15	7	6.80	8
Land use	6.52	8	6.01	5	6.47	7
Hazardous substances	7.49	9	7.96	9	5.83	6
Extinction of plants/animals	8.37	10	7.94	8	7.15	9
Nuclear reactors	8.38	11	9.82	12	8.98	11
Mineral resources	9.40	12	8.03	10	8.15	10

chemical engineering students take an optional course on environmental process engineering.

War technology, over a 10-year period, has been re-ranked from the fifth position initially designated by international science educators to the 11th and 12th positions assigned respectively by Cape Town science educators and undergraduate chemical engineers of the University of Cape Town. This change in position might be attributed to the agreed strategic arms limitations of the former USSR and the USA which, at this point in time, do not seem to threaten the Republic of South Africa.

The change in position of *human health*, during the last 10 years, from the sixth to the first and third positions, might be attributed to a more widespread awareness of diseases such as AIDS and an

increase in the incidence of skin cancers associated with depletion of the ozone layer [13-15].

High-quality education, geared towards finding creative solutions to pertinent and pervasive problems such as these, remains crucial for the practice and development of relevant engineering for the wider benefit of humanity.

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APPENDIX C:

**South African Institute of Race relations
survey (1994/1995)**

valued at R1,2bn had been seized in South Africa in 1993 (representing only about 10% to 15% of drug traffic) (see also chapter on *Security*).⁹¹

Chief Buthelezi said in August 1994 that the cabinet had set up an inter-departmental committee to deal with the problem of illegal aliens.

Refugees and asylum seekers

The Department of Home Affairs said in July 1994 that since the signing of an agreement between South Africa and the United Nations (UN) in September 1993 to allow political refugees into South Africa, a total of 1 117 applications for asylum had been received by the department. At the time of writing, none of these refugees had been granted asylum. According to the department, refugees and asylum-seekers who required assistance with, for instance, housing, were referred to non-governmental organisations. Asylum-seekers who found employment could apply to the department for permission to take up such employment, but would not be allowed to operate as hawkers.⁹²

In 1993 the UN High Commissioner for Refugees had started a two-year programme to repatriate some 250 000 Mozambican refugees living in South Africa.⁹³

The Provinces

According to the Development Bank of Southern Africa (DBSA), in 1993 KwaZulu/Natal had the largest number of inhabitants of all provinces, housing a fifth of the population of South Africa, or 8,5m people. The province with the smallest population was the Northern Cape, with 2% of the total (764 000 people). The Pretoria-Witwatersrand-Vereeniging (PWV) area had the highest population density (365 people per square kilometre), followed by KwaZulu/Natal (94) and the Northern Transvaal (43). The Northern Cape had the lowest population density (two people per kilometre).⁹⁴

Between 1985 and 1993 five provinces had average annual population growth rates higher than the national average of 2,44%, while three of these provinces — namely the Eastern Transvaal, the Northern Transvaal and the North-West — had growth rates of 3% or more. The Northern Cape had the lowest growth rate — under 0,8%.⁹⁵

In 1993 the highest degree of functional urbanisation (which includes people clustered around towns or in 'towns' without official recognition and people living in the vicinity of urban areas who are dependent on them for income) was recorded in the PWV (99,6%), followed by the Western Cape with 95% and KwaZulu/Natal with 78%. The lowest degree of functional urbanisation occurred in the Northern Transvaal (12,1%).⁹⁶

Fertility rate figures showed that in 1991 the Northern Transvaal had the highest fertility rate (5,9 children per woman), followed by the Eastern Cape with 4,6 and the North-West with 4,5 children per woman. The lowest fertility rate was recorded in the Western Cape (2,7).⁹⁷

In 1991 the PWV had the highest life expectancy in the country (65,5 years), while the Northern Cape recorded the lowest figure (59,6). According to the DBSA, the Western Cape had the highest literacy rate in 1991 (71,9%), followed by the PWV with 69%. The Northern Transvaal had the lowest literacy rate (52,7%).⁹⁸

The following table provides the most recent population and urbanisation statistics for South Africa's nine provinces:⁹⁹

Population and urbanisation statistics: provinces

Province	Population (000) (1993)	Population density (person/km ²)	Average annual population growth rate (1985-1993)	Functional urbanisation
Eastern Cape	6 665	39,1	2,6%	55,4%
Eastern Transvaal	2 839	34,7	3,0%	43,2%
KwaZulu/Natal	8 549	93,5	2,8%	77,9%
North-West	3 507	29,5	3,1%	43,9%
Northern Cape	764	2,1	0,8%	78,2%
Northern Transvaal	5 121	42,8	4,0%	12,1%
Orange Free State	2 805	21,7	1,5%	73,7%
PWV ^a	6 847	365,0	1,3%	99,6%
Western Cape	3 620	28,0	1,7%	95,1%
Average ^b	40 717 ^c	33,3	2,4%	65,5%

a Pretoria-Witwatersrand-Vereeniging.

b Averages were calculated using weighted figures.

c Total population.

Population and urbanisation statistics: provinces (continued)

Province	Fertility rate ^a (1991)	Life expectancy (years)(1991)	Literacy rate (1991)
Eastern Cape	4,6	59,6	67,7%
Eastern Transvaal	4,3	63,5	54,6%
KwaZulu/Natal	4,3	62,6	58,7%
North-West	4,5	64,1	55,8%
Northern Cape	2,9	64,0	67,6%
Northern Transvaal	5,8	62,7	52,7%
Orange Free State	3,7	63,6	60,0%
PWV ^b	3,0	65,6	69,0%
Western Cape	2,7	64,8	71,9%
Average ^c	3,3	63,4	61,4%

a The average number of children born live to a woman during her child-bearing years (15-49).

b Pretoria-Witwatersrand-Vereeniging.

c Averages were calculated using weighted figures.

APPENDIX D:

**Perceptions of professional ecologists and
business leaders in South Africa on
environmental issues**

Environmental issues in South Africa: Perceptions of professional ecologists and business leaders

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Human population growth is rated by both professional ecologists and business leaders as the most serious environmental issue facing South Africa. Other issues which emerged as very important are water availability, soil erosion, rural development, urbanization, desertification, and distribution of wealth. However, education, job creation, housing and health and welfare are regarded by both groups to be more pressing issues facing South Africa at present, as well as in the foreseeable future. Nevertheless, both groups believe that environmental conservation should be receiving greater funding from the state, particularly at the expense of defence spending, the costs of 'apartheid', and perceived bureaucratic excesses. The overriding impression from these results is that both professional ecologists and business leaders agree that the key issues facing environmental conservation are of a social, economic and political nature. Whereas the professional ecologists would like to see the Department of Environment Affairs have the power to override the decisions of other government departments, the business leaders do not favour it having such a veto vote.

Bevolkingsgroei word deur beide professionele ekoloë en sakeleiers beskou as die ernstigste omgewingskwessie wat Suid-Afrika in die gesig staar. Ander kwessies wat baie belangrik blyk te wees, is wateroeseikbaarheid, gronderosie, landelike ontwikkeling, verstedeliking, en verdeling van rykdom. Die vraagstukke rondom onderwys, werkskepping, behuising en gesondheid en welsyn wat Suid-Afrika tans en in die afsienbare toekoms in die gesig staar, word egter deur beide groepe as dringender beskou. Nogtans glo albei groepe dat omgewingsbewing meer fondse van die staat behoort te ontvang, veral ten koste van verdedigingsuitgawes, die koste van 'apartheid' en burokratiese oordaad. Die oomeersende indruk van hierdie bevindinge is dat professionele ekoloë sowel as sakeleiers saamstem dat die sleutelkwessie wat omgewingsbewaring in die gesig staar, van 'n sosiale, ekonomiese en politieke aard is. Terwyl die professionele ekoloë sou wou hê dat die Departement van Omgewingsake die mag moet hê om besluite van ander staatsdepartemente op te hef, glo sakeleiers nie dat dié departement so 'n veto-mag behoort te hê nie.

Keywords: Attitudes, business leaders, economic development, environmental conservation, professional ecologists, South Africa

To whom correspondence should be addressed

Introduction

Perception of environmental issues in South Africa was one of the foci in a wide-ranging survey of business leaders' and professional ecologists' attitudes toward conservation and development in South Africa (Preston, in press; Preston, Fuggle & Siegfried (a)-(c), in press). The aim was to ascertain what these two important groups perceive to be the critical environmental issues, and how serious these issues are relative to social, economic and political concerns in South Africa. The respondents' scenarios of the future trade-off options between the issues were also sought, as were their attitudes on the government's apportioning of resources to environmental issues.

The views of professional ecologists are important because they are specialists trained to evaluate aspects of environmental change, while the business leaders' views are important because they are particularly influential in directing development options in South Africa. Factual knowledge of the attitudes of these two groups should facilitate the search for common ground between conservation and development in South Africa.

The hypothesis tested in this study was that there are significant differences between the professional ecologists' and business leaders' attitudes toward aspects of conservation and development. Secondary hypotheses were that certain biographical variables are the significant determinants of differences within each group (e.g. 'applied' versus 'research' ecologists; business leaders from 'primary impact' versus 'secondary impact' businesses).

Conclusions

Both professional ecologists and business leaders believe that population growth has reached a critical stage — that only the immediate resolution of the problems associated with this issue will stave off fundamental, irreversible consequences for South Africa. Other issues

emerging as very important are water availability, soil erosion, rural development, urbanization, desertification and distribution of wealth.

Water pollution is rated as a more serious issue than are air pollution and noise pollution, but none of these is regarded as among the most important environmental issues in South Africa at present. The same is true of waste pollution, sea fisheries, wilderness destruction, deforestation, and wildlife conservation.

The ratings of environmental issues by the professional ecologists are an aid to those in decision-making positions in government conservation bodies, non-government organizations, educational bodies, and funding bodies such as the Foundation for Research Development and the Human Sciences Research Council.

It is noteworthy that the business leaders' ratings of the environmental issues so closely resemble those of the professional ecologists (whose training ought to establish them as authoritative assessors of environmental priorities). However, the business leaders' rating of litter above invasive plants/animals suggests that they are the ones who place a greater emphasis on aesthetic aspects of environmental conservation. Indeed, one of the major points emerging from these results is the extent to which the professional ecologists have downplayed the relative importance of wildlife conservation.

Both groups agree that socio-economic issues, particularly education, but also job creation, housing and health and welfare, are the pressing issues facing decision-makers, worthy of greater concern than the combined environmental issues. The business leaders believe this with a greater intensity than do the professional ecologists. Both groups felt that government-funded transport does not have the status of the environmental issues, chiefly because most believed in the privatization of transport. This balance in priorities was not expected to alter dramatically by the time the South African population doubles, although the scenarios were that the combined environmental issues will come closer to being on an equal footing with the socio-economic issues, particularly job creation, housing and health and welfare.

A common sentiment is that environmental conservation should receive greater funding. This should be at the expense of issues considered to be receiving disproportionately high amounts, notably defence spending, perceived bureaucratic excesses, the policy of 'apartheid', and transport.

A significant difference between the two groups is that the professional ecologists support the notion that the Department of Environment Affairs be accorded a veto vote over the decisions of other departments — a situation not favoured by the majority of business leaders.

The overwhelming majority of respondents in both groups acknowledged the interdependence between environmental and social, economic and political concerns. An overriding impression is that both professional ecologists and business leaders agree that the key issues facing environmental conservation are of a social, economic and political nature — compounded by population growth.

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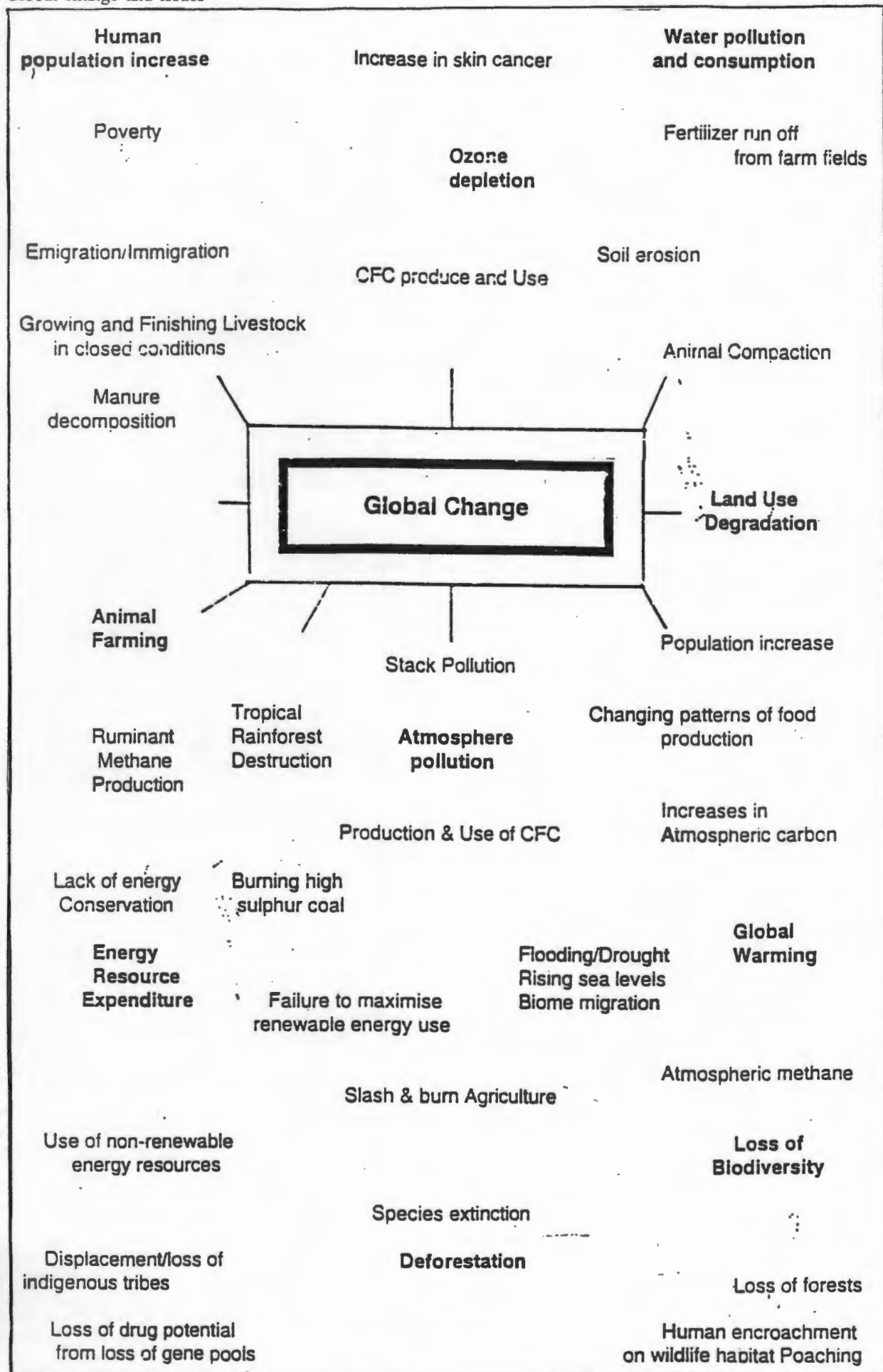
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APPENDIX E:

Global change and issues

Global change and issues



APPENDIX F:

Global calls for environmental education

Environmental education originated in the nineteenth century in response to the environmental impacts caused during the Industrial Revolution and was promoted by educationalists such as Patrick Geddes (1854-1933) and writers such as Rousseau and Emerson.

The environmental movement has led to the formation of international organisations which support and promote environmental education such as The International Union for the Conservation of Nature and Natural Resources (IUCN, 1948), World Wildlife Fund (WWF, 1961) and the United Nations Environmental Programme.

International conferences which have promoted environmental education include:

- 1972: International conference on the Human Environment at Stockholm, Sweden called for an international environmental education programme.
- 1975: International workshop at Belgrade, Yugoslavia led to the Belgrade Charter which outlines the aims, objectives and principles of environmental education.
- 1977: International conference at Tbilisi, USSR produced eleven directives principles for environmental education programmes documented in the Tbilisi Declaration.
- 1980: United Nations Educational, Scientific and Cultural Organisation (UNESCO) developed strategies for developing environmental curricula.
- 1987: International conference at Moscow, USSR drew up a strategy for the decade 1990 to 2000 (World Decade for Environmental Education).

DEVELOPMENTS IN SOUTH AFRICA

- 1982: International conference held at Treverton college, Mooi River leading to the formation of The Environmental Education Association of Southern Africa (EEASA).
- 1984: Conference at Midmar, Natal convened by the Council for the Environment to initiate a national policy on environmental education.
- 1989: White Paper on Environmental Education of 1989 which formulates the South African aims, objectives and principles for environmental education. This paper recommends the promoting, support and encouragement of actions at all government levels, by all formal education authorities and individuals and institutions concerned with non-formal and informal education (Blignaut, 1991: Appendix H).

APPENDIX G:

**Chemical engineering curriculum at the
University of Cape Town 1995**



UNIVERSITY OF CAPE TOWN

FACULTY OF ENGINEERING

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Upper Campus

Vice Chancellor's and Registrar's Offices
Bremner Building
Lower Campus
Lover's Walk
ROSEBANK

Office Hours: 08h30 – 12h30
13h30 – 16h30

The enquiries office and the central admissions office remain open during the lunch hour. The cash office is open on weekdays from 09:00 to 11:00 and 12:00 to 15:30.

This handbook is one of a series of 16 handbooks which is produced annually by the University of Cape Town

The series consists of:

- Book 1 Information for applicants for undergraduate degrees and diplomas
- Book 2 University Authorities and Staff
- Book 3 General Rules for Students
- Books 4-13 Handbooks of the Faculties of Arts, Commerce, Education, Engineering, Fine Art & Architecture, Law, Medicine, Music, Science and Social Science & Humanities
- Book 14 Fees
- Book 15 Financial assistance for undergraduate students
- Book 16 Financial assistance for postgraduate students

Chemical Engineering Curriculum

A candidate shall comply with the prescribed curriculum requirements set out below.

First Year Core Courses

Number	Course	Credits
CEM100W	Chemistry 100	9
CHE104W	Engineering I	8
MAM103W	Mathematics 103	8
MEC102W	Engineering Drawing	4
PHY110W	Physics 110	8
	Total credits	37

Second Year Core Courses

Number	Course	Credits
CEM203W	Pure Chemistry II	12
CHE215S	Heat Transfer	2
CHE216S	Fluid Flow	2
CHE223W	Chemical Process Analysis	10
EEE205F	Electrical Engineering	4
SMS201F	Calculus and Vector Analysis	2,5
SMS204S	Ordinary Differential Equations	2
SMS206F	Matrix Methods for Engineers	2,5
SMS302S	Partial Differential Equations	2
	Total credits	39

Third Year Core Courses

Number	Course	Credits
CHE328F	Introduction to Transport Processes	4
CHE329F	Solid-Fluid Operations	4
CHE333S	Mass Transfer Processes	4
CHE336W	Chemical Engineering Practical	2
CHE351F	Chemical Engineering Thermodynamics	4
CHE370S	Reactor Design I	4
PCU202F	Professional Communication	4
	Total credits	26
CHE300X	Practical Training	

Fourth Year Core Courses

Number	Course	Credits
CHE425Z	Chemical Engineering Project	7
CHE427F	Research Methodology (dp requirement)	0
CHE431F	Process Control	4
CHE436D	Chemical Engineering Design	7
CHE441F	Process Economics and Optimisation	4
CHE470F	Reactor Design II	4
EEE205F	Electrical Engineering	4
	Total credits	30

Elective Core Courses

At least 10 credits worth of courses must be selected.

GROUP A:

(Minimum 2 credits)

Number	Course	Credits
CEM304F	Physical Chemistry Laboratory	2
SMS203S	Engineering Statistics	2
SMS301F	Numerical Methods	2

GROUP B:

(Minimum 4 credits)

A list of courses satisfying this requirement is available from the Department of Chemical Engineering. Examples are

ECO202S	Economic History II: 20th Century Industrialisation	6
CAS100S	An Introduction to Africa	4

GROUP C

(Minimum 4 credits)

Number	Course	Credits
CHE335S	Bioprocess Technology	2
CHE337S*	Particulate Processes	2
CHE338S*	Surface Processes	2
CHE339S	Chemistry & Chemical Engineering of Catalytic Processes	2
CHE407F	Strategy of Design	2
CHE413F*	Introduction to Pyro- and Hydrometallurgy	2
CHE420F*	Practical Design of Minerals Processing Operations	2
CHE422F*	Coal Technology	2
CHE424F	Introduction to Environmental Process Engineering	2

or any approved Engineering course at or above the 3rd year level.

- CHE337S and CHE338S are compulsory for mining-house bursars.
- Any two of CHE413F, CHE420F or CHE422F are compulsory for mining-house bursars.

Optional Courses

A total value of not less than 4 credits must be selected from this category. These may be additional courses from the groups above or any other approved course or courses.

Conversion Programme for Science (BSc) Graduates

The following curriculum is applicable to BSc graduates who have been accepted into the conversion programme. The entrance requirements are as follows:

1. a BSc degree with at least an average of 60% in each major subject, or 60% in the final year for each major subject.
2. At least 60% in Chemistry II and Mathematics II or Applied Mathematics II.

CHE413F INTRODUCTION TO PYRO- AND HYDROMETALLURGY

24 lectures, 6 tutorials, 2 credits

Prerequisite: CHE337S

Course outline: Hydrometallurgy: leaching, separation, purification and enrichment, electrolytic processes, precipitation processes. Pyrometallurgy: roasting, smelting, refining.

June Examination: 3 hours

CHE420F PRACTICAL DESIGN OF MINERALS PROCESSING OPERATIONS

24 lectures, 6 tutorials, 2 credits

Prerequisites: CHE337S

Course outline: Conceptual flowsheet design. Sizing of equipment: crushing, milling, screens, cyclones, flotation cells, other assorted equipment. Design using simulation. This course includes a compulsory tour of the mines.

June Examination: 3 hours

CHE422F COAL TECHNOLOGY

24 lectures, 6 tutorials, 2 credits

Prerequisite: CHE337S

Course outline: The world coal industry. Origin, formation and classification of coal; chemical and physical characteristics. The South African coal industry; geology, mineralogy and exploitation of South African coals. Coal preparation with special reference to fines beneficiation. Flotation of South African coals. Typical plant flowsheets. Evaluation of plant performance. Coal utilisation: power generation, conversion to liquid fuels, metallurgical applications, as a chemical feedstock. Coal and the environment. The future of coal in South Africa.

June Examination: 3 hours

CHE424F INTRODUCTION TO ENVIRONMENTAL PROCESS ENGINEERING

24 lectures, 6 tutorials, 2 credits

Prerequisite: CHE223W

Course outline: Environmental resource management; identification of major pollutants in process industries; process design for waste minimization; technologies for gaseous, liquid, solid pollution control; hazardous waste management; environmental process engineering case studies.

Projects and assignments

CHE425Z CHEMICAL ENGINEERING PROJECT

7 credits

Prerequisites: Completion of First, Second and Third Year core courses. **Corequisite:** CHE427F

Course outline: An assigned experimental or theoretical investigation involving limited staff supervision. Assessment of performance is based on engineering ability and initiative displayed in formulation of objectives, execution of the project and presentation of the results.

Project

APPENDIX H:

**Critical values for Spearman's rank
correlation coefficient**

Critical values for Spearman's rank correlation coefficient

$$r_s = 1 - \frac{6D^2}{n^3 - n}$$

n	Significance Level			
	10%	5%	2%	1%
5	-	-	-	-
6	-	-	-	-
7	-	-	-	-
8	1.0000	-	-	-
9	0.9000	1.0000	1.0000	-
10	0.8286	0.8857	0.9429	1.0000
11	0.7143	0.7857	0.8929	0.9286
12	0.6429	0.7381	0.8333	0.8810
13	0.6000	0.7000	0.7833	0.8333
14	0.5638	0.6485	0.7455	0.7939
15	0.5364	0.6182	0.7091	0.7545
16	0.5035	0.5874	0.6783	0.7273
17	0.4835	0.5604	0.6484	0.7033
18	0.4837	0.5385	0.6264	0.6791
19	0.4464	0.5214	0.6036	0.6536
20	0.4294	0.5029	0.5824	0.6353
21	0.4142	0.4877	0.5662	0.6178
22	0.4014	0.4718	0.5501	0.5998
23	0.3912	0.4596	0.5351	0.5842
24	0.3805	0.4468	0.5218	0.5699
25	0.3701	0.4364	0.5091	0.5558
26	0.3608	0.4252	0.4975	0.5438
27	0.3528	0.4160	0.4862	0.5316
28	0.3443	0.4070	0.4757	0.5209
29	0.3369	0.3977	0.4662	0.5108
30	0.3306	0.3901	0.4571	0.5009
31	0.3242	0.3828	0.4487	0.4915
32	0.3180	0.3755	0.4401	0.4828
33	0.3118	0.3685	0.4325	0.4749
34	0.3063	0.3624	0.4251	0.4670

n	Significance Level			
	10%	5%	2%	1%
35	0.3012	0.3560	0.4185	0.4593
36	0.2962	0.3504	0.4117	0.4523
37	0.2914	0.3449	0.4054	0.4455
38	0.2871	0.3396	0.3995	0.4390
39	0.2829	0.3347	0.3938	0.4328
40	0.2788	0.3300	0.3882	0.4268
41	0.2748	0.3253	0.3829	0.4211
42	0.2710	0.3209	0.3778	0.4155
43	0.2674	0.3168	0.3729	0.4103
44	0.2640	0.3128	0.3681	0.4051
45	0.2608	0.3087	0.3636	0.4002
46	0.2574	0.3051	0.3594	0.3955
47	0.2543	0.3014	0.3550	0.3908
48	0.2513	0.2978	0.3511	0.3865
49	0.2484	0.2945	0.3470	0.3822
50	0.2456	0.2913	0.3433	0.3781
51	0.2429	0.2880	0.3396	0.3741
52	0.2403	0.2850	0.3361	0.3702
53	0.2378	0.2820	0.3326	0.3664
54	0.2353	0.2791	0.3292	0.3628
55	0.2329	0.2764	0.3260	0.3592
56	0.2307	0.2738	0.3228	0.3558
57	0.2284	0.2710	0.3198	0.3524
58	0.2262	0.2685	0.3168	0.3492
59	0.2242	0.2659	0.3139	0.3460
60	0.2221	0.2638	0.3111	0.3429
61	0.2201	0.2612	0.3083	0.3400
62	0.2181	0.2589	0.3057	0.3370
63	0.2162	0.2567	0.3030	0.3342
64	0.2144	0.2545	0.3005	0.3314

n	Significance Level			
	10%	5%	2%	1%
65	0.2126	0.2524	0.2980	0.3287
66	0.2108	0.2503	0.2956	0.3260
67	0.2091	0.2483	0.2933	0.3234
68	0.2075	0.2463	0.2910	0.3209
69	0.2058	0.2444	0.2887	0.3185
70	0.2042	0.2425	0.2865	0.3161
71	0.2027	0.2407	0.2844	0.3137
72	0.2012	0.2389	0.2823	0.3114
73	0.1997	0.2372	0.2802	0.3092
74	0.1982	0.2354	0.2782	0.3070
75	0.1968	0.2337	0.2762	0.3048
76	0.1954	0.2321	0.2743	0.3027
77	0.1940	0.2305	0.2724	0.3006
78	0.1927	0.2289	0.2706	0.2986
79	0.1914	0.2274	0.2688	0.2966
80	0.1901	0.2259	0.2670	0.2947
81	0.1888	0.2244	0.2652	0.2928
82	0.1876	0.2229	0.2635	0.2909
83	0.1864	0.2215	0.2619	0.2891
84	0.1852	0.2201	0.2602	0.2872
85	0.1829	0.2174	0.2570	0.2837
86	0.1807	0.2147	0.2539	0.2804
87	0.1785	0.2122	0.2510	0.2771
88	0.1765	0.2097	0.2481	0.2740
89	0.1745	0.2074	0.2453	0.2709
90	0.1725	0.2051	0.2428	0.2680
91	0.1707	0.2029	0.2400	0.2651
92	0.1689	0.2008	0.2375	0.2623
93	0.1671	0.1987	0.2351	0.2597
94	0.1654	0.1967	0.2327	0.2571

For description, see page 35.

Critical values for Kendall's rank correlation coefficient

$$\tau = \frac{N_C - N_D}{\frac{1}{2}n(n-1)}$$

n	Significance Level			
	10%	5%	2%	1%
5	-	-	-	-
6	-	-	-	-
7	-	-	-	-
8	1.0000	-	-	-
9	0.8000	1.0000	1.0000	-
10	0.7333	0.8667	0.8667	1.0000
11	0.6190	0.7143	0.8095	0.9048
12	0.5714	0.6429	0.7143	0.7857
13	0.5000	0.5556	0.6667	0.7222
14	0.4667	0.5111	0.6000	0.6444
15	0.4182	0.4909	0.5636	0.6000
16	0.3939	0.4545	0.5455	0.5758
17	0.3590	0.4359	0.5128	0.5641
18	0.3628	0.4066	0.4725	0.5165
19	0.3333	0.3905	0.4667	0.5048
20	0.3167	0.3833	0.4333	0.4833
21	0.3088	0.3876	0.4265	0.4706
22	0.2941	0.3464	0.4116	0.4510
23	0.2865	0.3333	0.3918	0.4386
24	0.2737	0.3263	0.3789	0.4211
25	0.2667	0.3143	0.3714	0.4095
26	0.2641	0.3074	0.3593	0.3939
27	0.2569	0.2984	0.3518	0.3913
28	0.2464	0.2899	0.3408	0.3768
29	0.2400	0.2867	0.3333	0.3667
30	0.2368	0.2800	0.3292	0.3600
31	0.2308	0.2707	0.3219	0.3581
32	0.2275	0.2646	0.3122	0.3439
33	0.2217	0.2611	0.3103	0.3399
34	0.2184	0.2552	0.3011	0.3333

n	Significance Level			
	10%	5%	2%	1%
35	0.2129	0.2516	0.2946	0.3247
36	0.2097	0.2460	0.2903	0.3228
37	0.2045	0.2424	0.2879	0.3144
38	0.2014	0.2371	0.2799	0.3119
39	0.1968	0.2336	0.2773	0.3042
40	0.1937	0.2317	0.2730	0.3016
41	0.1922	0.2282	0.2673	0.2973
42	0.1892	0.2233	0.2632	0.2916
43	0.1876	0.2200	0.2605	0.2874
44	0.1846	0.2179	0.2564	0.2846
45	0.1805	0.2146	0.2537	0.2805
46	0.1777	0.2125	0.2497	0.2753
47	0.1781	0.2093	0.2470	0.2735
48	0.1734	0.2072	0.2431	0.2685
49	0.1717	0.2040	0.2404	0.2667
50	0.1691	0.2019	0.2386	0.2638
51	0.1674	0.1989	0.2359	0.2599
52	0.1667	0.1968	0.2323	0.2571
53	0.1633	0.1956	0.2296	0.2534
54	0.1624	0.1918	0.2278	0.2506
55	0.1608	0.1906	0.2251	0.2488
56	0.1584	0.1885	0.2232	0.2459
57	0.1567	0.1872	0.2206	0.2438
58	0.1558	0.1852	0.2187	0.2411
59	0.1542	0.1825	0.2162	0.2391
60	0.1519	0.1805	0.2143	0.2364
61	0.1516	0.1792	0.2118	0.2343
62	0.1494	0.1773	0.2099	0.2317
63	0.1479	0.1759	0.2086	0.2297
64	0.1469	0.1740	0.2068	0.2282

n	Significance Level			
	10%	5%	2%	1%
65	0.1454	0.1727	0.2044	0.2262
66	0.1444	0.1719	0.2025	0.2237
67	0.1429	0.1705	0.2012	0.2227
68	0.1419	0.1687	0.1994	0.2202
69	0.1404	0.1673	0.1981	0.2183
70	0.1394	0.1655	0.1963	0.2168
71	0.1389	0.1642	0.1949	0.2148
72	0.1370	0.1633	0.1932	0.2133
73	0.1364	0.1620	0.1918	0.2114
74	0.1354	0.1611	0.1901	0.2099
75	0.1340	0.1598	0.1887	0.2089
76	0.1330	0.1581	0.1878	0.2074
77	0.1324	0.1575	0.1865	0.2055
78	0.1314	0.1559	0.1847	0.2040
79	0.1301	0.1553	0.1834	0.2029
80	0.1291	0.1537	0.1825	0.2014
81	0.1285	0.1531	0.1811	0.2003
82	0.1275	0.1515	0.1795	0.1988
83	0.1269	0.1509	0.1788	0.1970
84	0.1259	0.1500	0.1772	0.1962
85	0.1244	0.1478	0.1749	0.1936
86	0.1228	0.1457	0.1727	0.1910
87	0.1212	0.1442	0.1710	0.1885
88	0.1196	0.1426	0.1688	0.1865
89	0.1186	0.1406	0.1665	0.1845
90	0.1171	0.1390	0.1648	0.1820
91	0.1155	0.1375	0.1631	0.1801
92	0.1145	0.1360	0.1614	0.1785
93	0.1134	0.1349	0.1597	0.1765
94	0.1119	0.1333	0.1580	0.1745

Critical values for nonparametric tests with large samples

For all the eight tests dealt with on pages 26-34 there are approximate methods for finding critical values when sample sizes exceed those covered in the tables.

Approximate critical values for the sign test, Wilcoxon signed-rank test and Mann-Whitney U test may be found from the table of percentage points of the standard normal distribution on page 20. Denote by z the appropriate percentage point of the standard normal distribution, e.g. 1.9600 for an $\alpha_2 = 5\%$ two-sided test or 1.6449 for an $\alpha_1 = 5\%$ one-sided test. Then calculate μ and σ from the table below. The required critical value is $[\mu - z\sigma - \frac{1}{2}]$, the square brackets denoting the integer part.

	μ	σ
sign test	$\frac{1}{2}n$	$\frac{1}{2}\sqrt{n}$
Wilcoxon signed-rank test	$\frac{1}{2}n(n+1)$	$\{\frac{1}{2}n(n+1)(2n+1)\}^{1/2}$
Mann-Whitney U test	$\frac{1}{2}n_1n_2$	$\{\frac{1}{2}n_1n_2(n_1+n_2+1)\}^{1/2}$

For example in the sign test with sample size $n = 144$, $\mu = \frac{1}{2}(144) = 72$ and $\sigma = \frac{1}{2}\sqrt{144} = 6$, so that the $\alpha_2 = 5\%$ critical value is $[72 - 1.96 \times 6 - \frac{1}{2}] = [59.74] = 59$, i.e. the $\alpha_2 = 5\%$ critical region is $S \leq 59$. The reader may verify similarly that (i) for the signed-rank test with $n = 144$: $\mu = 5220$, $\sigma = 501.428$, and the $\alpha_2 = 5\%$ critical region is $T \leq 4236$; and (ii) in the Mann-Whitney test with sample sizes 25 and 30: $\mu = 375$, $\sigma = 59.161$, and the $\alpha_2 = 5\%$ critical region is $U \leq 258$.

For the Kolmogorov-Smirnov goodness-of-fit test, approximate critical values are simply found by dividing the constants b in the following table by \sqrt{n} :

α_2	5%	2½%	1%	½%
α_2	10%	5%	2%	1%
b	1.2238	1.3581	1.5174	1.6276
c	0.8255	0.8993	0.9885	1.0500

So with a sample of size $n = 144$, the $\alpha_2 = 5\%$ critical value is $1.3581/\sqrt{144} = 0.1132$, i.e. the critical region is $D_{144} > 0.1132$. The same constants b are used to obtain approximate critical regions for the Kolmogorov-Smirnov two-sample test. In this case b is multiplied by $\{1/n_1 + 1/n_2\}^{1/2}$ to give critical values for D (not D^*). So with sample sizes 25 and 30, $\{1/n_1 + 1/n_2\}^{1/2} = \{1/25 + 1/30\}^{1/2} = 0.2708$ and the $\alpha_2 = 5\%$ critical region is $D > 1.3581 \times 0.2708 = 0.3678$. For the Kolmogorov-Smirnov test for normality (with unspecified mean and standard deviation), the critical values are found as in the goodness-of-fit test except that the second row of constants c is used instead of b . In this case the $\alpha_2 = 5\%$ critical region with $n = 144$ is $D_{144} > 0.8993/\sqrt{144} = 0.0749$.

Finally, the Kruskal-Wallis and Friedman test statistics are, for large sample sizes, both distributed approximately as the χ^2 distribution with $\nu = k - 1$ degrees of freedom. The appropriate values have been inserted at the ends of the tables on pages 32-34; α_1^R values from the χ^2 table (page 21) are appropriate.

Linear and rank correlation

When data consist of pairs (X, Y) of related measurements it is often important to study whether there is at least an approximate linear relationship between X and Y . The strength of such a relationship is measured by the linear correlation coefficient ρ (rho), which always lies between -1 and $+1$. $\rho = 0$ indicates no linear relationship; $\rho = +1$ and $\rho = -1$ indicate exact linear relationships of $+ve$ and $-ve$ slopes respectively. More generally, values of ρ near 0 indicate little linear relationship, and values near $+1$ or -1 indicate strong linear relationships.

Tests, etc. concerning ρ are formulated using the sample linear correlation coefficient $r = \Sigma(X - \bar{X})(Y - \bar{Y}) / \{\Sigma(X - \bar{X})^2 \Sigma(Y - \bar{Y})^2\}^{1/2}$, \bar{X} and \bar{Y} being the sample mean values of X and Y . The first table on page 36 is for testing the null hypothesis H_0 that $\rho = 0$. Critical regions are $|r| > \text{tabulated value}$ if H_1 is the two-sided alternative hypothesis $\rho \neq 0$ (using significance levels α_2) or $r > \text{tabulated value}$ or $r < -(\text{tabulated value})$ if H_1 is $\rho > 0$ or $\rho < 0$ respectively (using levels α_1^R).

The following data show the market value (in units of £10000) of eight houses four years ago (X) and currently (Y).

X	0.8	1.7	2.4	0.9	1.2	1.6	1.7	2.9
Y	1.3	3.3	3.8	1.1	2.4	3.1	3.5	3.9

Here r is found to be 0.8918. This is very strong evidence in favour of

the one-sided $H_1: \rho > 0$, since the $\alpha_1^R = \frac{1}{2}\%$ critical region with sample size $n = 8$ is $r > 0.8343$. Had α_1^L critical values been required, they would have been given by the α_1^R values prefixed with a minus sign.

The construction of confidence intervals for ρ and the testing of values of ρ other than $\rho = 0$ may be accomplished using Fisher's z -transformation. For any value of r or ρ , this gives a 'z-value', $z(r)$ or $z(\rho)$, computed from

$$z(r) = \frac{1}{2} \log \frac{1+r}{1-r}$$

and $z(r)$ is known to have an approximate normal distribution with mean $z(\rho)$ and standard deviation $1/\sqrt{n-3}$. A table giving $z(r)$ is provided on page 36, and on page 37 there is a table for converting back from a z -value to its corresponding r -value or ρ -value. If r or ρ is $-ve$, attach a minus sign to the z -value, and vice versa.

So to find a $\gamma = 95\%$ confidence interval for ρ with the above data, we first find the 95% confidence interval for $z(\rho)$ as $\{z(r) - 1.9600/\sqrt{n-3}; z(r) + 1.9600/\sqrt{n-3}\}$ (the 1.9600 being the $\gamma = 95\%$ value in the table of normal percentage points on page 20) where $n = 8$ and $z(r) = z(0.8918)$, which is about 1.4306 (interpolating between $z(0.891) = 1.4268$ and $z(0.892) = 1.4316$ on page 36). This interval works out to (0.554; 2.307). These limits for the value of $z(\rho)$ are then converted to ρ -values by the table on page 37, giving the confidence interval for ρ of (0.503; 0.980). As a second example, if we wish to test $H_0: \rho = 0.8$ against $H_1: \rho > 0.8$ at the $\alpha_1^R = 5\%$ significance level, the critical value for $z(r)$ would be $z(0.8) + 1.6449/\sqrt{n-3} = 1.0986 + 1.6449/\sqrt{5} = 1.834$ (the 1.6449 again coming from page 20). The critical region $z(r) > 1.834$ then converts to $r > 0.950$ from page 37, and so we are unable to reject $H_0: \rho = 0.8$ in favour of $H_1: \rho > 0.8$ at this significance level.

An alternative and quicker method is to use the charts on pages 38-39. For confidence intervals, locate the obtained value of r on the horizontal axis, trace along the vertical to the points of intersection with the two curves labelled with the sample size n , and read off the confidence limits on the vertical axis. For critical values, locate the hypothesised value of ρ , say ρ_0 , on the vertical axis, trace along the horizontal to the points of intersection with the two curves, and read off the critical values on the horizontal axis. If these two values are r_1 and r_2 , with $r_1 < r_2$, then the one-sided critical regions with significance level α_1 for testing $H_0: \rho = \rho_0$ against $H_1: \rho < \rho_0$ or $H_1: \rho > \rho_0$ are $r < r_1$ and $r > r_2$ respectively, and the critical region with significance level $\alpha_2 = 2\alpha_1$ for testing H_0 against $H_1: \rho \neq \rho_0$ is comprised of both of these one-sided regions.

The reader may check the charts for the results found above using the z -transformation. Accuracy may be rather limited, especially when r and ρ are close to $+1$ or -1 ; however the z -transformation methods are not completely accurate either, especially for small n . Further inaccuracies may occur for sample sizes not included on the charts, in which case the user has to judge distances between the curves.

All of the above work depends on the assumption that (X, Y) has a bivariate normal distribution. Tables for two nonparametric methods, which do not require such an assumption, are given on page 40. These methods do not test specifically for linearity but for the tendency of Y to increase (or decrease) as X increases.

To calculate Spearman's rank correlation coefficient, first rank the X -values and Y -values separately from 1 to n , calculate the difference in ranks for each (X, Y) pair, and sum the squares of these differences to obtain D^2 . Spearman's coefficient r_s is calculated as $r_s = 1 - 6D^2/(n^3 - n)$. With the above data we have:

X -ranks	1	5½	7	2	3	4	5½	8
Y -ranks	2	5	7	1	3	4	6	8
rank differences	-1	½	0	1	0	0	-½	0

Thus D^2 is $2(1)^2 + 2(\frac{1}{2})^2 + 4(0)^2 = 2\frac{1}{2}$, giving $r_s = 1 - 6 \times 2\frac{1}{2}/(8^3 - 8) = 0.9702$. The $\alpha_1^R = \frac{1}{2}\%$ critical region for testing against the tendency for Y to increase with X is $r_s > 0.8810$, so there is virtually conclusive proof that this tendency is present. The general forms of the critical regions are the same as for r above.

For Kendall's rank correlation coefficient, we compare each (X, Y) pair in turn with every other pair; if the pair with the smaller X -value also has the smaller Y -value, the pair is said to be *concordant*, but if it has the larger Y -value the pair is *discordant*. If N_C and N_D are the total numbers of concordant and discordant pairs, Kendall's coefficient τ is calculated as $\tau = (N_C - N_D)/\frac{1}{2}n(n-1)$, where in fact $\frac{1}{2}n(n-1)$ is the total number of comparisons made. Any comparison in which the X -values and/or the Y -values are equal counts $\frac{1}{2}$ to both N_C and N_D . Critical regions are of the same forms as with r and r_s . In the above example, $N_C = 26\frac{1}{2}$, $N_D = 1\frac{1}{2}$, and $\tau = (26\frac{1}{2} - 1\frac{1}{2})/28 = 0.8929$. This is again clearly significant of the tendency for Y to increase with X , since the $\alpha_1^R = \frac{1}{2}\%$ critical region is $\tau > 0.7857$.

Critical regions for large n may be found using the facts that, under the null hypothesis, r , r_s and τ have approximate normal distributions with zero means and standard deviations $1/\sqrt{n-1}$ for both r and r_s , and $\{2(2n+5)/9n(n-1)\}^{1/2}$ for τ . For example the reader may check that with $n = 144$ the approximate $\alpha_2 = 5\%$ critical regions are $|r| > 0.1639$, $|r_s| > 0.1639$ and $|\tau| > 0.1102$.

APPENDIX I:

**Photocopies of some of the
recommendations made by Cape Town and
Transkei science educators**

What are your recommendations for teaching about these global problems?

Perhaps the time has come for compulsory courses on 'Environmental Awareness' to be introduced to the school syllabus, maybe on a similar basis as music, physical education, religion education etc. are presently presented i.e. 1-3 lesson periods per week.

What are your recommendations for teaching about these global problems?

- ① Should be part of the prescribed syllabus starting from lower levels.
- ② Topics should be related to what is happening around the pupils' environment. (Appropriate examples)
- ③ As much as possible - personalise the problems to students.
- ④ Try to make the pupils²⁼ aware that it is part of them - not distant.

What are your recommendations for teaching about these global problems?

The teaching of science should be planned such that these problems are dealt with at from as early as the primary level.

What are your recommendations for teaching about these global problems?

Demonstrations

Excursions

Use films

Run projects

What are your recommendations for teaching about these global problems?

Use of technology like television, radio and use of posters like charts.

What are your recommendations for teaching about these global problems?

A healthy mind nurses a healthy thinking. Children since from their early age should be trained to think and act productively. To enable this, a school curriculum must have provision for health education and each school must be provided with a physical education

teacher. This must start from Junior Secondary School.

Man power and finance spent on war technology must be directed on eradicating world hunger, housing and basic human needs.

What are your recommendations for teaching about these global problems?

Use of toxic substances should be minimised so as to guard the ozone layer and natural vegetation should be targeted. There should be as to cultivate its awareness. Emission of greenhouse should be monitored.

What are your recommendations for teaching about these global problems?

I recommend that people should be educated, by all what is occurring in nature and human life. That should be done from all level of human standards. The scientist and the people working in laboratories should stop exposing

What are your recommendations for teaching about these global problems?

The Global Problems related to science and technology must be included in the school curriculum from std 3 upwards as a form of discipline with no option i.e. Compulsory subject which for example could be termed as "Hazardous science". P.T.O

2

As the Instructor carries out the Teaching on world developments due to science achievements, should also be coupled with the Hazardous contribution of science achievements, so that, the student is earlier enough well acquainted with the double-edged science contributions. This will make him/her aware of his role in the global problems solutions - hence will be continuity.

From GEOGRAPHY DEPT.

Lumka College

Mr. Madhorjit B.P.

are your recommendations for teaching about these global problems?

COMMUNITY-BASED ACTIVITIES ON SCIENCE EDUCATION
SHOULD BE ORGANIZED WHICH WOULD HIGHLIGHT
THESE PROBLEMS AND THEIR POSSIBLE SOLUTIONS.

(PTO if more space is required)

What are your recommendations for teaching about these global problems?

Through the teachings of Ecology & emphasis on interrelationships between the various components on earth.

What are your recommendations for teaching about these global problems?

These global problems must be taught at schools so that people out there must be aware in that case problems will be minimized.

What are your recommendations for teaching about these global problems?

The students have to be made aware of these problems. Enough education/information about them should be readily available.

What are your recommendations for teaching about these global problems?

It is very important that the community in general be educated/made aware of ^{all} the topics above. Through ignorance, human beings are responsible for ~~ie~~ they ~~have~~ ^{offer} a certain ^{amount} contribution to the (i.e. a cause) problems above.

What are your recommendations for teaching about these global problems?

Excursions, Audiovisual with historical backgrounds & developments.

What are your recommendations for teaching about these global problems?

People should be made to be aware of all these by using all the possible methods. These methods may include the media of TVs, and the inclusion of these hazards and their consequences in the school curriculum.

What are your recommendations for teaching about these global problems?

Topics 1 to 4 should be instilled from very early age with scientific indications made clear.

Problems 7 & 8 should be coupled onto the relevant chemistry and physics topics from standard six.

The information should be built into the content/syllabus and not be a matter of the teachers' choice which would depend on whether the teacher himself has that kind of information.

E.g. when teaching about the periodic table, those elements that are, say, used in nuclear weapons should be dealt with and further indicated possible measures to manage nuclear waste.

OR. in item 8 from simple organic compounds how synthetic fuels are made, they don't have to make them as such but be shown what ingredients are necessary basically.

Good Luck.

Hebe.

P/s. I wish to see a copy of this work when completed

Thanks

What are your recommendations for teaching about these global problems.

Science and technology are necessary for human progress. But these developments should not lead to human destruction. They are necessary evils in the modern time. Scientists and technologists should spend their valuable time to find means to discuss their inventions and

rather than destructive purposes.

2. The world resources must be made available for the whole population of the world. A fair distribution of wealth must be made. Developed countries must begin to see the need for marketing part of their resources to developing countries.

3. The World Health Organisation should look into the areas affected worst in respect of health due to shortage of medicine and food.

4. A world-wide campaign is urgently needed to prevent the spread of deadly disease.

5. Population explosion must be checked with a matter of priority.

6. Organisations and structures must be set up world-wide to educate the illiterate and make them understand the need for family planning and the advantage of having less number of children.

7. If the world population control is successful there would be enough food available for the citizens of the world.

Intake of nutrient food would reduce the severity of diseases and reduce mortality.

2

the pupils will have some idea about these problems confronting the world. They do a lot about energy and natural resources and see how the population explosion is causing overexploitation of the resources and the use of fertilisers and insecticides which pollute the land and water. They must understand that it is the greed for consumer goods that cause the increase of factories and industries that pour out CFC into the atmosphere and cause depletion of the ozone layer.

What are your recommendations for teaching about these global problems?

Pupils must first of all know the different kinds of air present in the atmosphere, the importance of these air to plants and animals. Especially the ozone layer protecting life, and how is being affected by the presence of certain chemicals. The second important problem to be looked at, the land use, disposal of hazardous substances which might lead to the contamination of water e.g. sea water and estuaries.

2

eventually leading to the extinction of plants and animals. Show the pupils the importance of science technology i.e. advantages and also its disadvantage to life.

Try to show the link among all the 12 points and their effect if they are treated almost equally and be balanced. For example population growth might if not well monitored

What are your recommendations for teaching about these global problems?

Nuclear reactors are dangerous as they are a threat to the ozone layer. I would suggest that the pupils should be taught to use ozone free kindly chemicals. I would also recommend that pupils should be taught to practise ^{birth control} demography in order to arrest the population growth. The failure to arrest the population growth may result in territorial wars

and famine, soil erosion and the population will leave live above the carrying capacity of which will cause more deaths and diseases. The pupils must be also taught about the adverse effects of the depletion of ozone global warming e.g. they themselves will be scratched the ozone layer is allowed to deplete. To conclude, I therefore recommend that all the above mentioned topic deserve their rightful places in the syllabus.

What are your recommendations for teaching about these global problems?

It is a good idea to make pupils aware of the above problems. They can be included under Health Education and Environmental Studies. Some of the above are already included in Biology and Geography. We can stress these problems so that

rather than destructive purposes.

- 2, The world resources must be made available for the wide population of the world. A fair distribution of wealth must be made. Developed countries must begin to see the need for marketing part of their resources to developing countries.
- 3, The World Health Organisation should look into the areas affected worst in respect of health due to shortage of medicine and food.
4. A world-wide campaign is urgently needed to prevent the spread of deadly disease.
5. Population explosion must be checked with a matter of priority.
6. Organisations and structures must be set up world-wide to educate the illiterate and make them understand the need for family planning and the advantage of having less number of children.
7. If the world population control is successful there would be enough food available for the citizens of the world. Intake of nutrient food would reduce the severity of diseases and reduce mortality.

the toxic chemicals and nuclear waste. Things that need man's decision people should be consulted, and that particular thing should be attended to soberly.

What are your recommendations for teaching about these global problems?

All the above-mentioned global problems should be taught, discussed and debated both in the high school and training school. Students must be encouraged to play an active role in Environmental Conservation. They should be given a chance to read journals, see video programmes and attend seminars on Environmental and global problems.

What are your recommendations for teaching about these global problems?

These problems are not easy to rank because they are all important and interdependent. It is important therefore when teaching not treat them as isolated problems.

What are your recommendations for teaching about these global problems?

These should be included in the education curriculum because they are the problems of the society. For education to be effective, it should try and solve the social problems like these.

What are your recommendations for teaching about these global problems?

Use media e.g. Television to let the people see these problems and think about them.

What are your recommendations for teaching about these global problems?

These problems should be added to the school curriculum so that the kids should be aware of their problems at an ~~early~~ early stage.

What are your recommendations for teaching about these global problems?

This is a very serious matter which has to be addressed to all people in this world i.e. people must be made aware of the consequence of science & technology. More students must be encouraged to go in for science oriented courses as they will assist in spreading the message.

What are your recommendations for teaching about these global problems?

Integrate into relevant sections of Science, Biology and or Geography. Preferably have an integrated subject.
- Environmental Science

What are your recommendations for teaching about these global problems?

Subjects which deal with environmental studies should be given first preference.
Population growth should be controlled.

What are your recommendations for teaching about these global problems?

- Overpopulation should be prevented. The carrying capacity of the carrying land is an important factor in planning the size of the population. - Man must develop problem solving strategies and communication skills to change his environment substantially.
- Ways must be found to control the exponential growth of the human population if not we will run out of food and space.
- High density among a population, too much contact and conflict with other members of a population can be one of the causes of social stress. Birth control must measures be enforced by the state.

What are your recommendations for teaching about these global problems?

Importance should be given to the teaching of these problems in schools as well as to the community through mass media.

What are your recommendations for teaching about these global problems?

It is a good idea to make pupils aware of the above problems. They can be included under Health Education and Environmental Studies. Some of the above are already included in Biology and Geography. We can stress these problems so that

the pupils will have some idea about these problems confronting the world. They do a lot about energy and natural resources and see how the population explosion is causing overexploitation of the resources and the use of fertilisers and insecticides which pollute the land and water. They must understand that it is the greed for consumer goods that cause the increase of factories and industries that pour out CFC into the atmosphere and cause depletion of the ozone layer.

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All the above-mentioned global problems should be taught, discussed and debated both in the high school and training school. Students must be encouraged to play an active role in Environmental Conservation. They should be given a chance to read journals, see video programmes and attend seminars on Environmental and global problems.

What are your recommendations for teaching about these global problems?

1. Students must be taught the importance of family planning. They should not resort to indiscriminate creation of unwanted kids.
2. They must be taught that there is dignity (in doing hard) work.
3. They should be taught not to destroy the environment. We must not pollute water and air. We should not

destroy trees. If we cut one tree we must plant two to replace them. 4. The no. of sheep, goats and cattle we grow should not be in too large a number - so that the land available can not support them. 5. Students must be taught the importance of cleanliness and prevention of diseases.

What are your recommendations for teaching about these global problems?

Reduction of nuclear arms development and an increase in the development and learning about better and safer ways in the production of food. Safer methods towards curbing the rise in the spread of infectious diseases.

What are your recommendations for teaching about these global problems?

I believe it is our duty as educators to make people aware of the damage they do to the environment by using coal stoves, disposing waste anyhow and the damage done by industries by polluting the atmosphere. If a section on

pollution of the environment could be included in our syllabuses at an early age, it might help in making students environmentally conscious. If NGO's could also campaign strongly against population, whether it be water pollution, population with water or pollution of the atmosphere, then many people could become aware of the dangers that science & technology is posing on our society. To me all these problems are equally important and it is our duty to promote environmental education in our communities, schools and in the rural communities.

What are your recommendations for teaching about these global problems?

Optimal utilisation and conservation of natural resources should be the starting point in Natural and Biological Sciences such as Biology, General Science, Health Education, Agricultural Science. In each of these subjects the emphasis must be on working with nature and not

What are your recommendations for teaching about these global problems?

I recommend that these should be incorporated in the school curriculum as early as primary level. They should form the core-curriculum of the school system and should not be treated as alternatives, as they threaten the very existence of life.

What are your recommendations for teaching about these global problems?

People should be thoroughly taught about land conservation and have land available to them. Population growth programmes should be developed with all pertaining to population development. Nature conservation awareness should be instilled in the education of people as well as water conservation.

Physical substances should not be used excessively e.g. toxic chemicals. War technology (advanced) should be discouraged, because that will lead to the destruction of the ozone layer due to the manufacturing of chemical or nuclear material. This all depends on the harmonisation of the relationship between population development and nature conservation.

What are your recommendations for teaching about these global problems?

The relevancy of educating the population on these matters are unavoidable. Method: (1) Problem (present situation)

(2) What led to the situation

(3) Both return from the people find ways to combat the problem.

ACTIVITIES → (A) Promotion days of a specific theme
EX. (2) WATER RESOURCES → ^{one drop} makes the difference

(B) Videos given at schools

(C) Assignments given to students (in groups) at school

DTN

What are your recommendations for teaching about these global problems?

Media should be used to reach the whole spectrum of community

- Hunger and food resources are very important. Populations are increasing and the need for food is increasing.

② As the population grows, there is need of more energy and food source hence there must be knowledge of saving energy; producing energy by various other methods.

③ Each of the above-mentioned global problems should be explored in detail in the classroom. Each subject should be dealt with practically by giving ample examples from the world where these difficulties are being experienced.

Methods of conservation and prevention of the occurrence of these problems should also be taught. Each student must also be taught to look after and maintain his/her own environment. They should recycle paper and plastic cans, they should be taught to use environmentally friendly goods. Conservation of energy, proper usage of water resources and proper farming methods at their homes should also be encouraged.

Projects and competitions on Environmental conservation and global problems should also be conducted. Each student should be personally involved in finding solutions.

APPENDIX J:

**Documentation of the suggestions made in
December 1993 by lecturers in the Faculty of
Engineering at UCT**

Additional major global problems in science and technology:-

[].....

TECHNOLOGICAL ILLITERACY OF DECISION MAKERS

EMERGENCE AND SEPARATION OF C.P. SNOW'S "TWO-CULTURES"

Additional major global problems in science and technology:-

[] THE MYTH OF THE PEACE DIVIDEND

Even though less is being spent on armaments, the money saved is not going into new technology to solve the above. This must be addressed.

Additional major global problems in science and technology:-

[X] MASS HOUSING, SANITATION (provision of)

* JOB CREATION

— both could fall under categories already listed!

* WEATHER & CLIMATE: extreme phenomena such as drought & floods: the prediction and possible control.

Additional major global problems in science and technology:-

[].....

INFORMATION EXPLOSIONS (demands on the human race are becoming too great!)

Additional major global problems in science and technology:-

- [] I would add URBANIZATION as a major problem, not hide it as a petty land use (as done above). It is a many faceted problem encompassing sociology, systems engineering, water supply, waste water treatment, land use etc etc.

Additional major global problems in science and technology:-

- [] OCEANIC RESOURCE (overfishing, pollution, rising sea levels, ability to absorb more CO₂ and the effect of this.)

Additional major global problems in science and technology:-

- [✓]

ABUSE OF HIGH TECHNOLOGY (Global indoctrination of the masses by TV, Creation of hybrid bio-electric systems, Genetic engineering devoid of an understanding of the role that chaos plays in ensuring the survival of life, Proliferation of doubtful information via satellite)

Additional major global problems in science and technology:-

- [] HOUSING/INFRASTRUCTURE

Additional major global problems in science and technology:-

[]^(pollution)
ELECTROMAGNETIC WAVE HAZARDS! (MICROWAVE, EFFECTS ON
HUMANS AND ANIMALS.)

Additional major global problems in science and technology:-

[] Resource depletion (unless it is included
already under e.g. Mineral Resources)

Under Air Quality etc. - CO₂ is part of global
warming. Maybe you should include photochemical
smog.

Additional major global problems in science and technology:-

[] COMMUNICATIONS TECHNOLOGY:
DISSEMINATION OF KNOWLEDGE,
EDUCATION.

Additional major global problems in science and technology:-

[] Hazards associated with electrical power
sources i.e. Batteries of -:
Nickel - Lithium.

APPENDIX K:

Table 5.2 and Xhosa version of Table 5.2

**Table 5.2: Ranking of science-and technology-related global problems in 1995:
a proposed new instrument**

SECTION A

What do you see as the most important global problems related to science and technology? Rank the following from 1 to 15 (with 1 indicating your top priority). Insert your numbers in the appropriate brackets.

- [] HAZARDOUS SUBSTANCES (waste dumps, toxic chemicals lead paint).
 - [] HUMAN HEALTH AND DISEASE (infectious and non-infectious disease, stress, noise, diet and nutrition, exercise, mental health).
 - [] MINERAL RESOURCES (non-fuel minerals, metallic and non-metallic minerals, mining, technology, low grade deposits, recyclic, refuse).
 - [] WATER RESOURCES (waste disposal, estuaries, supply, distribution, ground water contamination, fertiliser contamination).
 - [] POPULATION GROWTH (world population, immigration, carrying capacity, foresight capability).
 - [] EXTINCTION OF PLANTS AND ANIMALS (reducing genetic diversity, wildlife protection).
 - [] ENERGY SHORTAGES (synthetic fuels, solar power, fossil fuels, conservation, oil production).
 - [] WAR TECHNOLOGY (nerve gas, nuclear developments, nuclear arms threat).
 - [] AIR QUALITY AND ATMOSPHERE (acid rain, carbon dioxide, depletion of ozone, global warming).
 - [] WORLD HUNGER AND FOOD RESOURCES (food production, agriculture, cropland conservation).
 - [] LAND USE (soil erosion, reclamation, urban development, wildlife habitat loss, deforestation, desertification, salinisation).
 - [] NUCLEAR REACTORS (nuclear waste management, breeder reactors, cost of construction, safety, terrorism).
 - [] USE AND ABUSE OF HIGH TECHNOLOGY COMMUNICATION (global indoctrination of masses by television, the creation of hybrid bioelectric systems, job creation, genetic engineering, proliferation of doubtful information by satellite).
 - [] ABUSE AND DEPLETION OF OCEANIC RESOURCE (overfishing, pollution, rising sea levels, effects of the ability of the oceans to absorb more carbon dioxide).
 - [] PROVISION OF MASS HOUSING AND INFRASTRUCTURE (homes for all, shelter, protection, social services such as police force and postmen, streetlighting).
-

APPENDIX K:

Xhosa version of Table 5.2

Qaphela: Zinike elinye igama (codename) xa ungafuni ukusebenzisa elakho.

UKUBEKWA EZINGENI KWEZENZULULWAZI KWANEZOBUNGCALI-IINGXAKI ZELIZW
EZICHAPHAZELEKAYO

Ziziphi ezona ngxaki uzibona njengezona zibalulekileyo ehlabathini ngokuphathelele ekusetyenzisweni kwezengcali nezenzululwazi entlalweni yabantu? Linganisela ezi zilandelayo ukususela ku 1-15 (ubonise okuthatha njengokona kubalulekileyo kuwe). Fakela amanani akho kwizivalelo (brackets) ezifanelekileyo.

IINGXAKI ZELIZWE

- () UKWAKHIWA KWEZINDLU EZININZI ZOKUHLALISA ABANTU (amakhaya alungele wonke umntu, kwanokuthuthwa kwenkunkuma nococeko lwangasese, iindawo zokufihla intloko, ukhuseleko, izibane ezitalatweni, iinkonzo zentlalontle ezinjengomkhosi wamapolisa noonoposi).
- () IZINTO EZINOBUONGOZI (iindawo zokulahla inkunkuma, iikhemikhali ezinobungozi, iilead paints, ielectro-magnetic wave radiation umz: iultraviolet radiation evela elangeni ne microwave oven radiation).
- () IMPILO NEZIFO (izifo ezibulalayo nezingabulaliyo ezifana ne gawulayo; umthambo; izigulo zengqondo; ukudinwa, ingxolo ukutya nesondlo).
- () IZIMBIWA (EZIVUTHAYO NEZINGAVUTHIYO, ezisisinyithi nezi ngesiso sinyithi, ezemigodi, ezengcali, ezikwinqanaba eli phantsi, irecycling, imigqomo).

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- () AMANZI ACOCEKILEYO (inkunkuma, umlambo, ukusetyenziswa kwamanzi, ukungcoliseka kwamanzi asemhlabeni, ukungcolisa kwezichumisi, ukuphathwa kwamanzi angasese, uqaphelo nolawulo lwezantyalu tyala zemvula kwanembalela)
 - () UKWANDA KOLUNTU (Ehlabathini, uthutho/imfuduko, indawo yokuhlala, ucwangwiso lwedolophu).
 - () UKUTSHITSHA KWEZITYALO NEZILWANYANA (ukusala kwentlobo zezilwanyana ezimbalwa, ukuloba okubaxwayo, ukungcoliseka nokucutheka kwezilwanyana nezityalo zaselwandle, ukukhuseleka kobomi basendle (izityalo nezilwanyana).
 - () UKUNQONGOPHALA KWAMANDLA (amandla enziwe ngabantu, amandla elanga, amandla embiwayo/amalahle, ukunqongophala kwemithombo ugcino lwamahlathi, imveliso ye-oli.)
 - () UBUNGCALI BEZEMFAZWE (i-nerve gas, ukwakhiwa kweze-nuclear, ilifu lezixhobo ze-nuclear elothusayo).
 - () UNGCOLISEKO LOMOYA (imvula ye-acid, CO₂, ukucutheka kwe-Ozone, umsi ongcolisayo, i-global warming).
 - () INDLALA NOKUFUMANEKA KOKUTYA (imveliso yokutya, izityalo nendlela zolimo).
 - () UKUSETYENZISWA OKUNGEKUKO KOMHLABA (ukhukuliseko lomhlabane, ukuncipha komhlaba, ukwanda nokukhula kwedolophu, ukuswela kwendle indawo zokuhlala, ukususwa kwamahlathi, ukukhula

kwentlambo, ukwanda kwetyuwa emhlabeni).

- () IZITISHI ZE-NUCLEAR (ulawulo lolahlo lwenkunkuma ye-nuclear, uxabiso lokwakhiwa, ukhuseleko, izenzo zobhukuqo).

- () UKUSETYENZISWA OKULUNGILEYO NOKUNGALUNGANGA KWEZOBUNGCALI OBUKWINQANABA ELIPHEZULU (i-electronic information explosion imfundo nokusasazwa kolwazi, i-genetic engineering, unxibelelwano lomhlaba ngokubanzi, ukwakhiwa kwemisebenzi, imfundiso zomabonakude, ukwahlulelana okukhawulezileyo ngenkcukacha ezingaginyisi mathe/ezixhalabisayo nge-satelite

- () ABAQULUNQI MTHETHO ABANGACHUBEKANGA (inkokheli zasekuhlaleni ezingenalwazi ngenzululwazi nezengcali; inzululwazi nezoluntu njengezithethe ezahlukeneyo).

Valela ibe nye kwezi zilandelayo ngesangqa:-

Indoda	Ibhinqa
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Std. 6	Std. 7	Std. 8	Std. 9	Std.10
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